# Evaluation of Interim Instream Flow Needs in the Klamath River

## Phase I

## Final Report

Prepared for:

Department of the Interior

Prepared by:

Institute for Natural Systems Engineering
Utah Water Research Laboratory
Utah State University
Logan, Utah 84322-4110

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## Executive Summary

This report reviews the historical and existing status of the anadromous fish within the lower Klamath River (i.e., below Iron Gate Dam) and highlights those factors which have been attributed to the decline in these fisheries. The report also makes interim minimum monthly flow recommendations for the main stem Klamath River below Iron Gate Dam downstream to the Scott River. These interim minimum instream flow recommendations are based on a variety of hydrology based modeling approaches which represent different, yet valid approaches to estimating required flow regimes. The report also provides a qualitative evaluation of additional factors such as temperature and habitat maintenance flows. The recommended interim minimum flows seek to provide the basis or starting point upon which restoration and maintenance of the aquatic resources within the Klamath River can be achieved in light of the Department of the Interior's trust responsibility to protect tribal rights and resources as well as other statutory responsibilities, such as the Endangered Species Act.

This report was developed for the Department of the Interior (DOI) who provided access to a technical review team composed of representatives of the U.S. Fish and Wildlife Service, Bureau of Reclamation, Bureau of Indian Affairs, U.S. Geological Survey and participation by the National Marine Fisheries Service. The technical review team also included participation by the Yurok, Hoopa, and Karuk Tribes given the Departments trust responsibilities and the California Department of Fish and Game as the state level resource management agency. The technical review team provided invaluable assistance in the review of methods used in the analysis, provided comments on the draft reports, various data and additional material for use in completion of the final report. In addition, several agencies and private individuals provided written comments on the Draft Report, which have been addressed in the report where appropriate.

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## Introduction

This report provides interim minimum flow recommendations, using the best available scientific methods given the available data, to address minimum instream flows required to support the ecological needs of aquatic resources, particularly anadromous fish species, in the Klamath River Basin. The report proposes minimum flows for the main stem Klamath River below Iron Gate Dam on an interim basis pending the completion of more intensive, site-specific instream flow analyses. The report outlines the approach taken to estimate minimum interim instream flow needs of the aquatic resources within the main stem Klamath River in California. The purpose of this effort is to recommend minimum flows within the main stem Klamath River below Iron Gate Dam on a monthly basis necessary to aid restoration efforts and the maintenance of the aquatic resources within the Klamath River in light of the Department of the Interior's trust responsibility to protect tribal rights and resources as well as other statutory responsibilities, such as the Endangered Species Act. Recommendations are made in light of existing literature and, where appropriate, hydrological based analyses and life history requirements of the anadromous species and related flow dependant aquatic resources (e.g., aquatic macroinvertebrates). It is recognized that many other factors within the Klamath Basin such as appropriate flow regimes within tributary systems and a variety of land use related efforts will be required before successful restoration can be achieved. The determination of interim minimum flow releases within the main stem Klamath River below Iron Gate Dam represents an important first step in this longer term effort necessary for the restoration of the anadromous fish within the Klamath Basin. For the purposes of this report and unless otherwise specifically stated, the Upper Klamath Basin is considered to be above Iron Gate Dam, while the Lower Klamath Basin lies below Iron Gate Dam.

## Background

Heightened consideration of necessary instream flow requirements in the Klamath River Basin has occurred since the passage of the 1986 Klamath River Basin Restoration Act, the development of annual and longer-term operations plans for the Bureau of Reclamation's Klamath Project, and the listing and proposed listings of Klamath River Basin anadromous fish. For the past 37 years, instream flows within the lower Klamath River have been substantially determined by the minimum flow regime specified at Iron Gate Dam under PacifiCorp's license from the Federal Energy Regulatory Commission. Although PacifiCorp is obligated to meet FERC minimum flows, they have operated the facility according to the Bureau of Reclamation Annual Operating Plans since 1996. Several instream flow studies or requisite components (e.g., suitability curve development) are currently underway in the Klamath Basin; however, these studies will not be completed for several years. As such, these studies cannot provide substantive input to the determination of the flow needs of the aquatic resources in the Klamath River on a more immediate basis; i.e., to provide scientifically based interim flow levels for tribal trust resources in the Klamath River in California for discussion and consideration in the on-going negotiations in the Upper Klamath

Basin adjudication in Oregon as well as the development of operations plans for the Klamath Project.

Although the “Trihey Report” - an interim instream flow analysis based on the Tennant method and developed by consultants to the Yurok Tribe-provided a sound rational basis for the recommendation of the instream flow needs for the purposes of the Klamath Project operations, a more detailed and expanded assessment was desired to address flow needs within the Klamath River Basin in California. The report is organized into three sections as follows:

**Chapter I Historical Conditions**

Chapter I focuses on a review of available historical information on the physical, chemical and biological conditions within the Klamath River, where in the context of this report, historical refers to pre-development conditions within the Klamath Basin. This section focuses on establishment of the historical context upon which existing conditions and recommended flow regimes can be assessed. Because of the integrated nature of the Klamath Basin as an ecological system, information is presented on the principal tributary systems in the Klamath Basin: Shasta, Scott, Salmon and Trinity Rivers. The report provides a synoptic overview of the life history requirements, spatial and temporal distributions, and potential limiting factors which may influence anadromous fish and other flow related aquatic resources.

**Chapter II Current Conditions**

This section of the report focuses on an assessment of the existing conditions within the Klamath Basin which have a direct or indirect effect on the flow dependent aquatic resources within the Klamath River. The report includes summary information on the temporal and spatial factors which have, or are suspected to have, impacted the resources both within the main stem Klamath River and its tributaries.

**Chapter III Assessment of Interim Flow Needs**

This section of the report provides a discussion of the methods and analyses utilized for recommending necessary interim minimum instream flows for the aquatic resources within the Klamath River pending further site specific studies. This section of the report emphasizes the assessment of an ecologically based minimum flow regime necessary to protect the physical, chemical and biological processes necessary to aid in the restoration and maintenance of the aquatic resources in light of the Departments statutory and fiduciary responsibilities within the Klamath River Basin.

# Chapter I - Historical Conditions

## Historical Fisheries Resources and Distributions

Both historical and existing distribution maps for fisheries resources within the Klamath River Basin discussed below are provided in Appendix A (USFWS 1999). The historical (pre-development) distribution of anadromous species within the Klamath River Basin extended above Upper Klamath Lake into the Sprague and Williamson River systems and Spencer Creek (Coots 1962, Fortune et al., 1966). Historical distributions in the Lower Klamath Basin (i.e., below Klamath Lake) included the Klamath main stem, Shasta, Scott, Salmon, and Trinity Rivers including many of the smaller tributary streams within the Lower Klamath River Basin. The anadromous species which utilized the Upper Klamath River Basin included chinook salmon and probably included steelhead and coho (e.g., CDFG 1954). The anadromous species in the Lower Klamath Basin include spring/summer, fall and winter run steelhead, spring and summer/fall run chinook, and coho. Other salmon reported from the Klamath include the chum and pink (Synder 1931). The Klamath Basin Ecosystem Restoration (1997) report lists chum salmon as being extirpated from the Klamath Basin but infrequent captures of both still occur.

Other important fisheries resources include white and green sturgeon, pacific lamprey, coastal cutthroat trout, and eulachon (candlefish) (KRBFTF 1991). However, lack of historical quantitative collection data (i.e., pre-1900's) makes the determination of the historical distribution of these species difficult beyond that of the main stem and tributaries in the Lower Klamath River.

### *Steelhead*

Historically, the Klamath supported large populations of spring/fall/winter run steelhead populations (Synder 1931, CDFG 1959, 1989). Steelhead were historically distributed throughout the main stem and principal tributaries within the Lower Klamath Basin such as the Shasta, Scott, Salmon, and Trinity River basins, and included many of the smaller tributary streams. Steelhead were also likely distributed in upstream tributaries of Upper Klamath Lake in the Upper Klamath Basin. Snyder (1931) and Fortune et al. (1966) indicate the likely presence of steelhead in the Upper Basin in the Sprague and Williamson Rivers but that the historical data was inconclusive. Steelhead are also known to utilize the main stem Klamath River in cold water refugia at tributary confluences (Belchik, pers. com). The fall/winter run steelhead utilized the Salmon, Scott, Trinity, and South and North Fork Trinity Rivers. In addition, Elk, Clear, Indian, Independence and Blue Creeks are known to contain fall steelhead. Historically however, steelhead would utilize any tributary with access for spawning and juveniles would migrate upstream in tributaries even where spawning habitat did not exist. Summer run steelhead are known to utilize the Salmon, New, Scott and South and North Fork Trinity Rivers, Wooly, Redcap, Elk, Bluff, Dillon, Indian, Clear, Canyon, Camp, Blue, Grider and Ukonom Creeks (see citations in KRBFTF 1991).

### *Coho Salmon*

The historical distribution of coho salmon in the Klamath River Basin is reported to have historically occurred in 113 tributary streams in the Klamath-Trinity River drainage (Brown and Moyle 1991). Their historical utilization of the Upper Klamath Basin is not known from conclusive records (Fortune et al., 1966). Historical data document the collection of coho as far upstream as the Klamathon Racks (Synder 1931) and are known to inhabit the Shasta, Scott, Salmon and Trinity River Basins. It is assumed that all tributaries with sufficient access and habitat supported coho.

### *Chinook Salmon*

The historical distribution of chinook salmon in the Klamath River Basin is known to have extended above Klamath Lake into the Sprague and Williamson Rivers (Fortune et al. 1966). They were also distributed throughout the Lower Klamath Basin in the principal tributaries (i.e., Trinity, Scott, Shasta, and Salmon Rivers) and several of the smaller stream systems such as Fall, Jenny, and Bogus Creeks (Coots 1962). Historically, spring chinook runs were considered to be more abundant prior to the turn of the century (Moyle 1976, Moyle et al., 1989) when compared to the dominance of summer/fall runs since that time (Snyder 1931). Spring chinook were historically collected in the vicinity of the current Iron Gate Dam (Iron Gate Hatchery records). During the pre-1900s some of the spring run chinook were destined for the Salmon River, other lower main stem tributaries and likely tributaries upstream of Klamath Lake (Snyder 1931, Fortune et al. 1966). The apparent shift to a summer/fall run population occurred by the end of the first decade following 1900 (see citations in Snyder 1931, Moffett and Smith 1950).

### *Green (and White) Sturgeon*

No quantitative data on the historical upstream distribution of green or white sturgeon are known but have been observed in the main stem Klamath River as far upstream as Iron Gate Dam. It is not known whether Klamath Lake would have posed an upstream migration barrier, though sturgeon are still found in Klamath Lake but are thought to be extremely rare (Belchik, pers. com.). Green sturgeon have also been observed in the Trinity and South Fork Trinity Rivers, and in the Salmon River (see citations in KRBFTF 1991).

### *Coastal Cutthroat Trout*

Coastal cutthroat trout are known to be distributed throughout the lower Klamath River tributaries but the population status and distributions are poorly known. Collections from the estuary, lower tributaries, and Hunter Creek are documented (see citations in KRBFTF 1991).

### *Eulachon (Candlefish)*

Eulachon are thought to extremely rare or extirpated in the Klamath River (Belchik, pers. com.). Historical use suggest that they utilized the lower 5 to 7 miles of the Klamath River during March and April for spawning. Eggs incubate for approximately two to three weeks and the larvae then migrate back to the ocean (Moyle 1976 as cited in KRBFTF 1991).

### *Pacific Lamprey*

The distribution of lamprey in the Klamath River is poorly known. Lamprey have been observed on salmon at the Klamathon Racks and collected from Cottonwood Creek near Hornbrook (Coots 1962) which may represent a non-anadromous form in the Klamath Basin. Lamprey have also been observed in the Trinity River and dwarfed landlocked forms have also been reported from the Klamath River above Iron Gate Dam and in Upper Klamath Lake. Lamprey are also suspected of utilizing the Scott, Shasta, and Salmon Rivers (see citations in KRBFTF 1991).

## Life History Traits

The following section provides a synoptic description of key life history traits for each of the species. For a more complete treatment of life history traits the reader is referred to Leidy and Leidy (1984), BOR (1997), DOI (1985) and KRBFTF (1991).

### *Steelhead*

The Klamath Basin supports three runs of steelhead generically referred to as spring/ summer, fall and winter runs. Typically mature spring/summer steelhead enter the Klamath River between mid-April to late May. These fish migrate upstream to most of the principal tributaries including many of the larger creeks where they hold until spawning between January/April of the next year. Weir counts on the New River which is approximately 84 miles from the delta showed adult summer steelhead show downstream migration in mid-March, peaked in mid-April and diminished by the end of May (USFWS pers. com.). Fall run steelhead will typically enter the River as early as July, but primarily during October and November were they hold for several months before moving to spawning areas in smaller tributaries. Winter run steelhead typically move into the River between December through February and may continue through May while migrating to their spawning areas. Approximately 16 to 22 percent of spawning steelhead are repeat spawners (USFWS pers. com.) One of the more unique characteristics of the Klamath River Basin is the presence of half pounders. These steelhead are immature (non-spawning) males and females, which are found in the summer and fall run steelhead migrations. Half pounders that enter the Klamath River generally return to the ocean the following winter or spring. After egg deposition, eggs typically incubate from 4 to 7 weeks with the fry typically emerging during

March through June. The length of time for egg incubation is a function of water temperature. The juveniles may remain in freshwater for one to three years before emigration. Emigration of natural steelhead smolts from the Klamath Basin typically occurs between March to late July. Field collections suggest that most emigrating steelhead arrive in the estuary during April and May. Although steelhead utilize the Klamath River as a migratory corridor to access spawning tributaries, some spawning does occur in the main stem. Its importance to resident life stages throughout the year cannot be understated. For example, a large percentage of wild Klamath River steelhead show two years of freshwater growth and a half-pounder life stage exists. Tributary out-migration data show that a large percentage of steelhead entering the Klamath are fry and yearlings that must rear in the main stem for an additional year or two. Half-pounders rear in the Klamath and tributaries from August-April. Steelhead prefer water temperatures which range between 7.2 and 14.4 C . Optimal growth temperatures range between 10.0 and 12.8 C. Upper lethal limits on temperature have been reported as 23.9 C.

### *Coho Salmon*

Coho typically migrate into the Klamath River during mid-September through mid-January. Upstream migrations are typically associated with pulse flows due to fall rain events. Although coho primarily spawn in tributary streams from November through Jan. they have been observed spawning in side channels, at tributary confluences, and suitable shoreline habitats in the main stem. Egg incubation lasts approximately seven weeks and typically occurs during November through March. Alevins remain in the gravel approximately two to three weeks and then emerge as free swimming fry during February to mid-May with the peak in April and May. Coho will typically rear in freshwater for one year before emigrating to the ocean. This usually occurs in the spring following the first winter. Out migration can begin as early as February and continue through mid-June, with peak numbers arriving in the estuary during April and May. Optimal temperature ranges for coho are 3.3 to 20.5 C, although preferred rearing temperatures are 12.0 to 14.0 C. Upper lethal temperatures have been reported as 25.6 C.

### *Chinook Salmon*

Spring chinook salmon typically enter the Klamath River as early as February through the month of July. Peek immigration has been reported as occurring from March to mid-June. Migrating adults tend to hold in deeper pools of the tributaries where they remain throughout the summer before spawning in the fall. Spawning may occur from September through mid-November. Spring chinook spawning in the Salmon River occurs from mid-September through mid-October. Spring chinook are generally believed to migrate farther upstream than the fall runs. Once the eggs are deposited incubation generally occurs from 40 to 60 days. Alevins and fry remain in the gravel for approximately two to four weeks and begin to emerge during December. However, USFS emergence traps on the Salmon River show emergence extending into late May. Optimal incubation temperatures range between 4.4

and 13.3 C. Spring chinook will typically hold in freshwater for approximately one year with emigration generally occurring through March to July although USFS Salmon River outmigration traps show that spring chinook smolts emigrate during fall and spring months. Typical rearing habitats for juvenile spring chinook are runs and pools. Optimal temperature for juvenile spring chinook ranges between 13.9 C and 19.4 C. Upper threshold temperature for juveniles has been reported as 25 C.

Fall chinook are typically separated into two runs, fall and late fall runs. The fall run enters the Klamath river from mid-July through mid-October while the late fall run occurs from November through December with some as late as February. Fall chinook spawning occurs throughout the lower reaches of tributaries with less than one-third of the total fall chinook run utilizing the main stem Klamath River for spawning. Although approximately 50 percent of the main stem Klamath spawning occurs in the upper 13 miles, significant spawning occurs as far downstream as Happy Camp at river mile 110. Spawning, in limited numbers, has be observed downstream as far as Orleans. Egg incubation generally requires 50 to 60 days at water temperatures which range between 5 C and 14.4 C. Some have reported emergence of the fry from the gravel during the November to February period. However, Klamath River main stem spawning and temperature data collected by the USFWS in 1993 and 1994 was used to predict emergence timing for the 1994 and 1995 water years using daily temperature units. Emergence from the 1993 run began in early February and peaked in early March 1994 compared to water year 1995 when emergence began in early March and peaked in early April (USFWS pers. com.). Emergence timing in the tributaries is believed to be earlier than the main stem. Due to different life history strategies, outmigration of natural chinook is year round. Type I chinook outmigrate in the spring and early summer months. Type II outmigrate in the fall and Type III hold over through the winter and migrate in early spring (Sullivan 1989). The majority of Klamath River chinook outmigrate using the Type I strategy. Mid-Klamath River tributaries such as Elk Creek have a Type II strategy. A wet and cold spring can cause a shift of the peak outmigration up to one month later than a dry warm water year. Young of year chinook outmigrating through the Big Bar trap subside in early August. Shasta River chinook outmigrate from late January through early May. The secondary pulse should not be confused with the fall, Iron Gate Hatchery release.

### ***Green Sturgeon***

Both white and green sturgeon have been found in the Klamath River, however the green sturgeon is the most abundant of the two. The white sturgeon are known to periodically migrate up the Klamath River (see citation in DOI 1985). Green sturgeon typically enter the Klamath River in late February and may continue to do so through late July. Although sturgeon have been observed as far upstream as Iron Gate Dam they typically do not migrate above Ishi Pishi Falls on the main stem Klamath. As noted previously migrating sturgeon also utilize the Trinity, South Fork Trinity, and lower Salmon River. Spawning typically occurs during March to July with peak spawning occurring during April, May to mid-

June. Emigration of post spawning adults generally occurs throughout the summer and fall with peaks in August and September. Out migration of sturgeon juveniles may occur when they are less than one year old or as long as two years old. Out migration begins in the upper reaches of the basin as early as July while peaking in September in downstream areas.

### *Coastal Cutthroat Trout*

It is believed that coastal cutthroat trout enter the Klamath River during the November through March period and spawn during the spring. Juveniles may rear for up to one or two years in either streams or the estuary before migrating to the ocean.

### *Eulachon (Candlefish)*

Eulachon typically enter the lower Klamath River during the March and April period and spawn immediately. Eggs typically incubate for two to three weeks after which the larvae out migrate.

### *Pacific Lamprey*

Very little information is known about the Pacific lamprey within the Klamath River Basin. The Yurok Tribal Fisheries Program has documented lamprey entering the Klamath River from October through April with the peak often occurring in December or January. Lamprey are thought to spawn during April to July. Egg incubation typically occurs over a two to three-week period with the ammocoetes remaining in the substrate for up to five or six years before out migrating. Emigration is thought to typically occur during the late summer months. However, observed immigrations in March appear to be associated with high flows (Walt Lara Sr. pers. com. cited by Belchik pers. com.). Lamprey have been observed spawning in Dillon Creek in June and eyed juveniles as free swimming and attached to steelhead in cool water refugia from Bluff Creek to Bogus Creek (Belchik, unpublished data).

## Historical Hydrology

Most of the existing stream gage records are highly impacted by upstream water use and therefore determination of historical conditions is difficult. The following summary is primarily taken from USGS (1995) which completed a characterization of hydrology data in the Klamath River Basin based on periods of record for existing gages. The analysis conducted by USGS indicated that at annual flow-volume level, gage data do not strongly reflect changes in water allocation strategies in the main stem Klamath River near Keno, the Shasta River, the Scott River, or the Salmon River. However, flow alterations (e.g., depletions and seasonal shifts in the magnitude) are evident at the monthly level. The annual flow regime downstream of Lewiston in the Trinity River clearly reflects the large trans-Basin diversions which began in 1961 with the construction and operation of the Central Valley Project Trinity

River Division. This change in hydrology becomes less detectable downstream during high flow periods due to unimpaired runoff at downstream locations in the Trinity River and is not readily apparent in main stem of the Klamath during the spring runoff period in normal and above normal water years.

One of the more unique characteristics of the historical flow regime of the main stem Klamath River was the rather 'smooth' annual hydrograph, which is attributed to the hydraulic buffering of the large storage capacity in Tule, Upper and Lower Klamath Lakes prior to development in the upper basin (Balance Hydrologics, Inc. 1996). Within year variability of flows on a seasonal and daily basis within the main stem below Copco are well-documented. In addition, seasonal shifts in the annual hydrograph are readily apparent due to water allocation practices in the upper Klamath Basin as reflected in the gage data below Iron Gate Dam, which are well-documented. These include flow depletions of 250,000+ acre feet and seasonal shifts in the pattern of the annual hydrograph. These changes are discussed further in Chapters II and III.

The following discussion on changes to within year hydrology is confined to the lower Klamath Basin and is presented here for convenience. The analysis by USGS concluded:

> " The Klamath River at Keno, Shasta River near Yreka and the Scott River near Ft. Jones are influenced by irrigated agricultural water use. Two of these locations show a discernible change in relative runoff compared to the Salmon River beginning about the1960's. ... we conclude this phenomenon is not due to changes in the Salmon River drainage, but due to changes in the upper Klamath and Scott basins. These changes could be due to changes in crop patterns, irrigation techniques, water demand due to a persistent change in summer weather patterns or other causes. We believe this phenomenon is related to man's activities."

The documented changes in flow below Iron Gate Dam in terms of annual flow depletions within the Upper Klamath Basin, changes in the seasonal distribution of flows, the current status of the anadromous stocks which include listed or proposed listing of fish under the ESA, curtailment and or loss of tribal, commercial, and recreational fishing opportunities, as well as historical and current concerns over the adequacy of the FERC flow regime highlights the need for an assessment of instream flow needs within the main stem Klamath River and tributary systems.

## Chapter II - Current Conditions and Historical Factors Affecting Fisheries Resources

### Current Distribution of Anadromous Species

Both historical and existing fish species distribution maps are provided in Appendix A. At the present, habitat of anadromous salmonids is limited in the Klamath River Basin to the main stem and tributaries downstream of Iron Gate Dam. Upstream distribution in several of the tributaries (e.g., Trinity) has also been limited due to construction of dams and diversions. Access to the Upper Klamath Basin by anadromous species was effectively stopped with the completion of Copco Dam No. 1 in 1917 although reduced access to tributaries in the Upper Klamath Basin likely occurred starting as early as the 1912-14 period with construction of the Lost River diversion canal and completion of Chiloquin Dam. Access to the upper reaches of the Trinity River and its tributaries were blocked in 1961 with completion of Lewiston Dam. The final reduction in upstream main stem habitat access occurred in 1962 with the completion of Iron Gate Dam. The following synopsis on the existing distribution of key species was primarily adopted from DOI (1985) and BOR (1997) and references contained in the annotated bibliography in Appendix C.

### Factors Attributed to the Decline of Anadromous Species

The decline of anadromous species within the Klamath River Basin can be attributed to a variety of factors which include both flow and non-flow factors. These include over harvest, affects of land-use practices such as logging, mining, stream habitat alterations, and agriculture. Other important factors have included climatic change, flood events, droughts, El Nino, fires, changes in water quality and temperature, introduced species, reduced genetic integrity from hatchery production, predation, disease, poaching. Significant effects are also attributed to water allocation practices such construction of dams which blocked substantial areas from upstream migration and have also included flow alterations in the timing, magnitude, duration and frequency of flows in many stream segments on a seasonal basis. The following synopsis is taken primarily from DOI (1985), BOR (1997), KBRBFTF (1991) and references in the attached annotated bibliography contained in Appendix C.

Based on a review of the literature examined for this study, it is reasonable to assume that the Klamath River Basin was primarily in a natural state prior to about 1800. However, by the mid 1800s a variety of factors were already contributing to the decline of the anadromous stocks. During this period both accelerated timber harvest, placer/gravel/suction mining, and commercial exploitation of salmon stocks were underway. Over exploitation of the commercial fisheries (ocean and in river), placer mining, and local dam construction were attributed to declining salmon stocks as early as the 1920s. Snyder (1931) considered the decline of the spring run chinook to have occurred prior to the closure of the river at Copco in 1917 and attributed this decline primarily to over exploitation of the salmon stocks and placer/gravel/suction mining in the Basin. The concern of over exploitation and declines in the anadromous stocks of the Klamath River Basin led to the closure of commercial fishing in 1933. Prior to the 1990's, excessive ocean harvest rates seriously reduced salmon stock abundance in the Klamath River System. Passage of the Pacific Fisheries Management Council’s Salmon Plan in 1978, followed by the formation of the Klamath River Salmon Management Group in 1985 and the Klamath River and the Klamath Fisheries Management Council in 1987 has led to improved management of Klamath Basin fisheries resources. During the 1980's, ocean harvest rates on age-4 Klamath fall chinook averaged 53 percent (PFMC 1991), however since 1991 the average age-4 ocean harvest is less than 12.5 percent (PFMC 1998). This reduction in ocean harvest is partially due to the recognition of river tribal fishing rights, as well as to regulations for conservation of Klamath Basin fall chinook. Age-4 river harvest rates have also substantially declined since 1990, dropping from an average of 65 percent from 1986-1989 to an average of 32 percent following 1989.

Timber harvest activities within the Klamath River Basin have also contributed to the long-term decline in the salmon stocks beginning from the turn-of-the-century. This included deterioration of habitat from increased sediment loading and general deterioration of large-scale watershed areas. The extensive placer/gravel/suction mining within the Basin resulted in serious habitat modifications beginning in the early 1900s and directly impacted salmon runs during this period. The extensive habitat modifications to both the main stem and tributary systems are still evident today (e.g., the Scott River).

Although upstream migration of the anadromous stocks were effectively blocked with the construction of Copco Dam in 1917, water allocation practices to meet agricultural demands in the upper Klamath Basin continued to affect downstream anadromous species due to alteration in the shape and magnitude of the hydrograph below Iron Gate Dam. Diversion of water to meet agricultural demands in both the Scott and the Shasta River systems are attributed to significant reductions in habitat availability and quality for spawning and rearing chinook. Depletion of stream flows in the Scott River and almost every tributary within this subbasin are associated with severe limitations for coho and steelhead juvenile rearing habitat availability and stranding of juvenile fall chinook, coho, and steelhead during the irrigation season in average and below average water years. Diversion of water for agricultural purposes, and the associated agricultural return flows, are attributed to higher than normal water temperatures and degraded water quality in both the Shasta and Scott River systems. Spring run chinook and spring run steelhead are considered to be extinct or at best remnant populations in the Scott and Shasta rivers and is attributed to poor summer flow conditions. Iron Gate Dam also blocked access to several cool water springs and tributaries below Copco Dam that were utilized by spring chinook such as Jenny and Fall Creeks. These creeks and the main stem Klamath River continued to support chinook prior to construction of Iron Gate Dam (Kent Bulfinch, pers. com. cited by Belchik, pers. com.).

Although historical data does not exist to determine the temperature and water quality regime of the main stem Klamath River below Klamath Lake, existing flows within the main stem Klamath River below the Scott River during the late summer period have been associated with conditions that can result in lethal combinations of high temperature and low dissolved oxygen, as evidenced by fish kills. Bartholow (1992) evaluated available water temperature data in the Klamath Basin and generally concluded that during low flow summer periods the natural conditions in the Klamath main stem are likely marginal for anadromous species due to elevated temperature. However, existence and use of thermal refugia is well documented.

It is evident from the available data that the completion of Copco Dam in 1917 and completion of Trinity Dam in 1962 significantly reduced the Basin wide distribution of anadromous species. However, the construction of dams associated with placer/gravel/suction mining, timber harvest, and fisheries practices impacted anadromous species prior to these major dams. For example, a splash dam constructed on the main stem Klamath River at Klamathon in 1889 effectively blocked upstream migration of anadromous species to the upper Klamath Basin until 1902. Effective blockage of several tributary streams by dams for mining also occurred in the 1930s, many of which were not removed until the 1950s. This included Hopkins, Camp, Indian, Beaver, Dutch and Cottonwood Creeks on the main stem Klamath, and several tributaries in both the Salmon and Scott River basins. Dwinell Dam was completed in 1928 on the upper Shasta River, which effectively blocked upstream migration. No minimum instream flow was required at this facility.

The existence of Trinity/Lewiston Dams, and Iron Gate Dam, and Dwinell Dam are also attributed to negative changes to the quality and quantity of available spawning gravels suitable for use by anadromous species below these facilities. Prior to the construction of Iron Gate Dam, hydropower releases (i.e., rapid flow ramping) were also associated with deleterious conditions for spawning and young of the year anadromous species in the main stem Klamath River. Iron Gate operations have flow ramping rate criteria under Article 40 of PacificCorp FERC License which states that a ramping rate not to exceed 3 inches per hour or 250 cfs/hour whichever produces the least amount of fluctuation as measured at the Iron Gate gage. PacificCorp voluntarily targets ramp rates at Iron Gate gage to approximate two inches per hour (Frank Shrier, pers. com.). Large-scale changes in the channel form below Trinity Dam are also known to have resulted in loss of productive salmon rearing habitat. Restoration of the channel is being recommended in the Trinity River Flow Evaluation Report by alterations in the Trinity flow release schedule as well as mechanical restoration activities but restoration of recommended restoration measures have not yet occurred. Recommendations from this study include both modification in the minimum instream flow requirements as well as the release of flood flows for rehabilitation of the riparian community and stream channel.

Additional factors which impacted the anadromous species in the Klamath Basin have included high pre-spawning mortalities in the 1950 through 1953 period and adverse effects due to extreme flooding in 1955, 1964, and 1974 and drought during 1976-77. The pre-spawning mortality was associated with hatchery produced fall chinook returning to the Fall

Creek Hatchery where over escapement to the Hatchery resulted in fish being forced back into the Klamath River where a lack of natural spawning gravel caused redd superimposition. In addition, suspected higher mortalities associated with angling is also suspected (see Appendix C). The extensive and extreme magnitude of fires in 1987 are also considered to have been deleterious to anadromous species due to the increased run off from the disturbed watersheds within the Klamath Basin. Cumulative impacts to many of the tributary watersheds in conjunction with alteration of the hydrograph below Iron Gate Dam is attributed to the formation and persistence of large delta fans at tributary confluences. These fans during periods of low flow may inhibit or have completely blocked access to these tributaries by anadromous species. Finally, concern has been raised over the increase predation of anadromous species by the resurgence of the sea lion populations at the mouth of the Klamath River and predation by brown trout below Lewiston Dam on the Trinity River. Although these other cumulative factors have contributed to limiting conditions for many of the aquatic resources, reduction in habitat access due to existing dams and continuing alterations in the flows (with associated deteriorated water quality) remain important limiting factors. This includes the downstream and cumulative effects of changes in flow and water quality in the main stem Klamath River.

***The Upper Klamath Basin***

The construction of Copco Dam was started in 1910 and likely impacted upstream migration of anadromous species at that time. The Dam was completed in 1917 and effectively eliminated over 100 miles of potential anadromous fish habitat in the upper Klamath Basin. The continuing effect on the lower Klamath Basin is primarily due to changes in the hydrology and potentially water quality. Releases below Iron Gate Dam have been associated with water temperatures above acute salmonid exposure criteria (i.e., 20 C) and dissolved oxygen below chronic exposure levels (i.e., 7 mg/l) during the late summer. Most water quality problems within the main stem Klamath River associated with fish kills have been reported below the Scott River. Although as noted previously, naturally high water temperatures were likely pre-main stem dam construction due to the large surface areas associated with Upper and Lower Klamath Lakes some mitigating inflows from springs and tributaries likely offset these temperatures to some degree and provided cool or cold water refugia to salmonids. Water allocation practices to meet agricultural demands now result in higher winter flows and lower summer flows compared to the natural hydrograph. Poor water quality arising from Upper Klamath Lake is a combination of natural high concentrations of nutrients in tributaries of Klamath Lake and nutrient enrichment due to land-use practices in the upper Basin. It may be difficult to ameliorate water quality in the Lower Klamath Basin given the water quality characteristics in the Upper Klamath Basin. Increased flows are anticipated to improve water quality to some degree, but changes in water management and land use practices may also be required to fully address water quality issues in the lower basin.

### *The Upper Trinity Subbasin*

With the completion of Trinity Dam and Lewiston Dam, access to the entire upper Trinity subbasin was effectively blocked for all anadromous species in 1962. This included spring and fall chinook salmon, coho, steelhead, and Pacific lamprey which were known to utilize this subbasin for spawning and rearing habitat (see Appendix A). Estimated losses for chinook spawning habitat is 59 miles and 109 miles for steelhead habitat. It is unknown how much coho habitat was lost but would likely be similar to chinook.

Prior to 1981 flows in the Trinity River below Lewiston were reduced by approximately 80 percent. In addition to a substantial reduction in the base flow regime, operations eliminated almost all flood events. This resulted in substantial channel alterations below the facility in the main stem of the Trinity River which are associated with deleterious conditions for anadromous species and major changes in the channel form. Pending the completion of the Trinity River Flow Evaluation Report and the associated EIS/EIR flows currently in the main stem Trinity River remain significantly reduced.

### *The Shasta Subbasin*

Water quality in the Shasta River has been impacted with the creation of Lake Shastina in 1928 which receives high nutrient loading due to upstream land-use practices. Problems associated with adverse water temperatures for anadromous species have been recognized in the Shasta River for over 20 years, which are attributable to the numerous water diversions on the Shasta River and its tributaries and agricultural practices within the Basin. The Shasta River has been highly impacted from grazing practices. The lack of large woody debris in the stream and loss of recruitment potential has decreased the complexity of the river channel from many years. The loss of significant riparian areas from over grazing has also been attributed to elevated adverse water temperatures. Several tributaries are also poorly connected to the main stem Shasta (e.g., Little Shasta Creek) and very low dissolved oxygen levels occur in some reaches during critical low flow summer periods (Deas, pers. com.).

Historical anadromous fish using the Shasta River basin include fall chinook, coho, fall steelhead and Pacific lamprey. Historical data indicate a decline in chinook spawning runs within the Shasta Basin since the 1930s. Available data for both coho and steelhead spawning runs are not entirely reliable to ascertain long-term population trends, although steelhead are considered to have experienced declines. It is estimated that the Shasta River presently maintains approximately 35 miles of fall chinook habitat and 38 miles of coho habitat and are similar to values reported in 1955 but remain below pre-development levels. However, actual utilization of this remaining habitat is contingent upon suitable flow conditions which may not be met during average and dry years due to water diversion. Fall steelhead habitat is estimated at approximately 55 miles and is somewhat reduced compared to estimates derived in 1955. Lake Shastina has likely blocked suitable habitat upstream that was historically utilized by steelhead in the headwaters of the Shasta River. The lack of gravel recruitment below Lake Shastina may also negatively affect river morphology and fish habitat. Accessibility to the currently available steelhead habitat is contingent upon suitable flow conditions and lack of migration barriers at agricultural diversions (see Appendix A).

Overall, anadromous fish production in the Shasta River basin is considered to be limited by low flows and high summer water temperatures, stream diversions and degraded spawning gravels. Cumulative depletions of water for agricultural use during the May through October period of average and dry years may restrict access by fall chinook to the lower 10 to 15 miles of the river. Low flow conditions during these types of water years also reduce suitable rearing habitat for both coho and steelhead juveniles. However, water quality in the Big Springs area remains tolerable for rearing juveniles through the summer months. These conditions are acerbated due to increased water temperatures which can exceed upper limits for the anadromous species. These conditions have resulted in a known fish kills for juvenile steelhead. Additional impacts within the Basin are associated with grazing practices which can result in increases in sedimentation which adversely affects steelhead spawning and rearing habitats. No quantitative data on the distribution or abundance of Pacific lamprey is currently known.

***The Scott Subbasin***

Principal factors affecting the distribution and quality of habitat within the Scott River basin are associated with the numerous agricultural diversions along the main stem of the River and its tributaries as well as the loss of beavers, grazing and levies which have contributed to degradation of habitat and alterations in the Scott River channel. . Existing diversions within the main stem Scott River and its tributaries exceed 650 cfs. The cumulative effects of these diversions are severely depleted instream flows in many sections. Additional flow reductions, including dry channels, have been associated with groundwater pumping for irrigated land use, which affect both tributary streams as well as the lower main stem Scott River.

Current anadromous use of the Scott River include fall chinook salmon, coho salmon, fall steelhead, and Pacific lamprey. Fall chinook salmon are known to utilize the main stem Scott River and several of its major tributaries. It is believed that both coho and steelhead are more widely distributed but no quantitative information exists to estimate runs sizes. Trend data on chinook salmon would appear to indicate a general decline in the Scott River basin since the 1960s at least. In the absence of more quantitative data it is assumed that the trends in coho and steelhead within the Scott subbasin are reflected in the overall trends for the remainder of the Klamath Basin at-large. However, during the past decade, steelhead numbers (fall, winter and spring/summer-run) have declined dramatically on the Klamath River side of the Klamath Basin relative to numbers found on the Trinity River side. Many of the index streams in this area of the Basin have their headwaters in wilderness areas, suggesting the limiting environmental bottleneck is in the main stem Klamath River (CDFG, pers. com.). It is estimated that approximately 59 total river miles of habitat within the Scott River, East Fork Scott River and lower Mill Creek currently exist for fall chinook. The estimated historical miles of available coho salmon habitat in the Scott River basin was 126 miles. Available data suggests that existing habitat now constitutes approximately 88 miles. The estimated extent of steelhead habitat is approximately 142 miles within this Basin (see Appendix A).

The anadromous fish production within the Scott River basin is impacted by reduced flows, degraded spawning habitat, high summer water temperatures, and several un-screened diversions. Cumulative water withdrawals in conjunction with groundwater pumping during the agricultural season of May to October currently limits upstream migration for fall chinook at approximately River mile 42. In average to dry years these low flows severely limit both coho and steelhead juvenile rearing habitat suitability and availability during the May to October period. These low flows in conjunction with agricultural return flows are also associated with high water temperatures in the main stem Scott River and many of its tributaries. Land-use practices have been noted to cause increase sedimentation problems over most of the main stem Scott River.

***The Salmon Subbasin***

The Salmon River represents one of the most pristine watersheds still existing within the entire Klamath River basin. Although a high percentage of the Salmon River is under a wilderness designation, other areas have significant road networks and have undergone significant timber harvest. In addition to the timber harvest practices, grazing and the 1987 fire have had negative affects on the Salmon River watershed and Salmon River channel. The Salmon River supports spring and fall chinook salmon, coho salmon, spring and fall steelhead, Pacific lamprey and green sturgeon. Fall chinook populations within the Salmon River have shown declines which are associated with factors external to the Salmon River. Insufficient data presently exists to make inferences on the status of coho populations within the Salmon River, but are believed to reflect overall trends within the lower Klamath River basin. The current status of steelhead populations are also not known but again, but summer steelhead numbers have stayed depressed in the Salmon River drainage and numerous other tributaries such as Clear Creek, Bluff Creek and Dillon Creek (CDFG, pers. com.). No quantitative information on the distribution and status of Pacific lamprey is known. No quantitative information on the status of green sturgeon populations is known and they are considered to inhabit the lower six miles of the Salmon River.

Current estimates of fall chinook habitat within the Salmon River are approximately 81 miles, which is approximately nine miles less than the highest historical estimates. Historical estimates of coho habitat within the Salmon River and its tributaries is approximately 105 miles. Existing estimates are approximately 85 miles. Historical estimates for steelhead and within the Salmon River do not exist but all are assumed to be similar to that of coho which would be approximately 109 miles (see Appendix A).

No significant impediments to anadromous fish production within the Salmon River basin currently exist. However, areas of unstable spawning gravels have been identified in reaches of both the North Fork and South Fork Salmon Rivers. Finally, elevated water temperatures which exceed upper growth requirements for salmonid juveniles have occasionally been reported. These events are attributed to natural climatic factors.

***The Mid-Klamath Subbasin***

The Klamath Task Force defines the Mid-Klamath Subbasin as the main stem Klamath River from Iron Gate Dam to Weitchpec. This section of the main stem Klamath River can be impacted by water quality from upstream releases at Iron Gate during low flow periods. Elevated water temperatures during the late summer period have been observed. In the past decade this reach of the main stem Klamath River has been impacted by reductions in water quality as a consequence of timber management and mining activities. These are primarily associated with increased turbidity. Water releases at Iron Gate Dam due to Klamath Project operations impact main stem river flows in this reach of river. Water allocation practices within both the Shasta and Scott River basins also contribute to flow alterations in this reach of river. Changes in the flow regime are generally reflected in increased winter flows and reduced summer flows when compared to historical conditions as noted by USGS (1995) and Balance Hydrologics, Inc (1996).

The main stem Klamath River and many of its tributaries are utilized by spring and fall chinook salmon, coho, and spring and fall steelhead. Pacific lamprey and green sturgeon are also known to utilize this reach of river. The main stem Klamath should not be considered only a migration corridor. In 1995, over 6,000 fall chinook spawned in the main stem (USFWS pers. com.). The production from these spawners must rear in the main stem through time of smoltification. In addition to the main stem recruitment, tributary pre-smolt outmigrants must rear in the main stem until smoltification. These fish rely on the main stem Klamath for up to 2 years. Lamprey and sturgeon rely on rearing in the Klamath rive for up to 5 or 6 years and 1 to 3 year, respectively. In addition, spawning in the main stem by chinook is known to occur from below Iron Gate downstream to Orleans. Overall trends in anadromous fish for this subbasin generally reflect the long-term declines for the Klamath River basin as noted previously. The remaining chinook populations are primarily composed of fall run. The specific status of coho within this reach of the main stem Klamath River and tributaries is also difficult to ascertain due to lack of site-specific quantitative data. In general it is assumed that populations follow the general trend for the lower Klamath River basin. This also applies to steelhead. No quantitative data are available on the status or distribution of Pacific lamprey but are believed to have river access similar to that of steelhead. No quantitative data for green sturgeon populations are available for this reach of river.

Estimated available habitat for spring and fall chinook is approximately 168 miles within this subbasin. The estimated available habitat for steelhead within this section of the mid Klamath Basin is approximately 250 miles of spawning in rearing habitat. Coho are estimated to have access to approximately 190 miles (see Appendix A).

Principal factors affecting anadromous fish production within this section of the Klamath Basin include high water temperatures and water quality (e.g., pH and dissolved oxygen), suspected loss of spawning gravels, flow reductions for some tributary systems, flow depletions within the Upper Klamath River Basin and altered characteristics in the timing and magnitude of main stem flows. In addition, Highway 96 and parallel roads to the main stem and tributaries have caused effects to fish habitats and access. Alterations in the channel due to upstream dams have been associated with armoring of the stream bed and lack of gravel recruitment from blocked upstream sources. Land-use practices in several of the tributaries have resulted in sedimentation which has adversely impacted fall chinook, steelhead, and coho production in Dry, Ten Mile, Elk, Indian, and Thompson Creeks. Several tributaries are also impacted by agricultural diversions either from un-screened diversions or flow reductions during the agricultural season. Land use practices such as logging, homesteading, road building, grazing, etc, have impacted many tributaries within this Subbasin and those mentioned previously are just examples.

### *The Mid-Trinity Subbasin*

Flow releases below Lewiston Reservoir had historically resulted in a much colder water temperatures during the summer and warmer temperatures during the winter when compared to natural conditions and have adversely impacted anadromous species. Alterations in the flow regime to address these issues are currently underway. During the period of 1963 and 1981 flows in the main stem Trinity below Lewiston Dam were reduced by approximately 80 percent and peak flows were essentially eliminated. This resulted in a substantial narrowing of the river channel and fossilization of point bars by riparian vegetation. This was associated with reduced quantity and quality of anadromous rearing habitat. Subsequently, improved minimum instream flows as well as initiation of higher flow events have been undertaken in an attempt to rehabilitate the river channel and associated riparian community.

Utilization of the mid-Trinity subbasin by anadromous species include fall and spring chinook, coho, spring and fall steelhead, green sturgeon, and Pacific lamprey. Overall populations of chinook are considered to have declined within this basin. Although escapement estimates for coho vary, there has not been a discernible decline noted for this basin since closure of Lewiston Dam. The estimates of the escapement from this section of the Klamath Basin clearly indicate a substantial decline for steelhead. No quantitative data exists to estimate populations status or trends for either the Pacific lamprey or green sturgeon.

Available habitat for both coho and chinook salmon are estimated at about 140 miles. Total estimated habitat for steelhead is approximately 225 miles. Green sturgeon are considered to have limited access to approximately nine miles of the main stem Trinity River downstream of Burnt Ranch (see Appendix A).

Although the most significant reduction in both quantity and quality of available habitat for anadromous species occurred with the construction of the Lewiston and Trinity dams, other factors such as poor land-use practices have also contributed. Additionally, significantly degraded habitat is attributed to the 1964 flood. Problems continue within this subbasin due to erosion, bank instability, and sediment input which had adverse impacts on available anadromous fish habitat.

The primary factors which are considered to limit anadromous fish production in the Trinity River subbasin include reduced flows from agricultural diversions, migration barriers, sedimentation, and riparian encroachment on the main stem Trinity River channel. Formation of tributary deltas have also occurred due to the lack of higher flow releases from the upstream dams which can inhibit or preclude access to tributaries by anadromous species during low flow periods. Formation of these deltas are also associated with increased sediment loads due to poor land-use practices in several of the tributaries. As noted previously, the lack of high flow events since closure of Lewiston Dam have resulted in significant encroachment by riparian vegetation which has led to alteration in the physical characteristics of the river channel. This general narrowing and deepening has resulted in significant losses to important early life stage rearing habitats for many of the anadromous species. Both the increased minimum flows and prescribed high flow events from Lewiston Dam are anticipated to improve these conditions. Although not a major factor, some agricultural diversions in the basin may unnecessarily reduce access to spawning in rearing areas for anadromous species. Finally, hydraulic and dredge mining activities have impacted the Trinity and its tributaries for many years.

### *The South Fork Trinity Subbasin*

Although no major water development has occurred within the South Fork Trinity River subbasin, sedimentation from the naturally erodible soils has increased due to poor land-use practices in the past, primarily by timber management activities. The 1964 flood resulted in a significant deterioration of anadromous spawning habitats in this tributary, which is still undergoing rehabilitation through natural processes today. Fires, timber harvest, road construction and historic mining practices with the added large flood events have all played a role in the loss of anadromous salmonid production within this Subbasin.

Historical distributions of anadromous species within the South Fork Trinity subbasin include fall, winter, and spring run steelhead, spring and fall chinook salmon, coho, green sturgeon, and Pacific lamprey. Overall trends for the anadromous species are generally considered to be in decline reflective of the entire lower Klamath Basin. No quantitative data presently exists to determine the populations status for Pacific lamprey and green sturgeon.

Existing estimates of available anadromous species habitat are considered to be nearer historical conditions than in previous decades after the 1800's and are attributable to habitat improvement efforts over the past 20 years. The estimated steelhead distribution indicates they have access to approximately 190 miles of river habitat, which include both spawning in rearing areas. Estimated coho habitat is approximately 115 miles in this basin. The current distribution of chinook within the basin indicates that existing available habitat is near historical levels and is approximately 115 miles. Although no quantitative data exists to estimate the distribution of Pacific lamprey they are currently believed to have access to similar areas as that of steelhead (see Appendix A).

The primary factors which affect anadromous fish production include sedimentation, reduced water quality, areas of reduced flows from agricultural diversions, hydroelectric developments, and upstream migration barriers at agricultural diversions. Adverse impacts due to sedimentation have been a historical problem throughout the subbasin due to the natural characteristics of the underlying geomorphology. These problems, however, have also been increased due to some historical land-use practices primarily associated with timber harvesting. Although natural in origin, the 1964 flood resulted in serious sediment induced problems such as disruption of spawning riffles, filling of rearing and holding habitats (i.e., pools), and in many locations stream channels were significantly widened and became shallower. In some instances the loss of the riparian community in conjunction with the widening of the stream channel has been attributed as the mechanism for elevated water temperatures which may limit the amount of anadromous species habitat in this system. Agricultural diversions primarily during the irrigation season are known to result in reduced flows in several of the tributaries which may impact rearing habitat for anadromous species in the Hayfork Creek watershed.

### *The Lower Trinity Subbasin*

Major factors which impact the salmonid production capacity in the lower Trinity River are due to upstream water allocation practices at Lewiston and Trinity dams. As noted previously, these diversions have resulted in a 70 to 90 percent reduction in base flows with operation of the Trinity River Division. This reach of the Trinity River has also experienced elevated water temperatures during the summer which has been attributed to reduced summer flows from upstream diversions in conjunction with lost riparian vegetation shading. Slightly increased releases subsequent to 1981 from Lewiston Dam have had no appreciable effect on the thermal regime or anadromous species habitat within this segment of the river however, the minimum prescribed flow pending the completion of the Trinity Flow Study and implementation of recommended measures still represents the third lowest flow of record. Historical water pollution problems have also been associated with fish kills within this section of the river but are not known to occur today.

This segment of the Trinity River contains important habitat for spawning fall chinook, spring chinook, winter and fall steelhead, coho, green sturgeon, and Pacific lamprey. Many of the tributary streams in this segment of the river are also important rearing habitats for these anadromous species. Coho are known to require one year of freshwater growth. Coho that exit tributaries within or outside of this subbasin that are pre-smolts, must rear in the main stem Klamath River until smoltification has completed. The overall population trends for chinook salmon follow those described for other segments of the Trinity River. Historical utilization of the Trinity by coho salmon is not well understood and it is felt that a few coho currently utilize this segment of the river for spawning and rearing. Reliable quantitative data for population trends for steelhead, spring chinook, green sturgeon and Pacific lamprey are not available for this area of the river. It is generally believed, however, that steelhead are below historical conditions in this basin (see Appendix A).

The historical distribution of chinook only indicate utilization of the main stem, and the degree to which tributary systems were utilized is unknown. No historical distribution data exists to estimate habitat use for coho, steelhead, green sturgeon, or Pacific lamprey. It should be noted that considerable restoration efforts for habitat improvement in the post 1964 flood event have occurred within this and upstream segments of the Trinity basin as a whole.

The primary factors which are considered to limit anadromous fish production in the lower Trinity subbasin include loss of juvenile rearing habitat as a consequence of high summer water temperatures within the main stem, reduction in suitable spawning gravels from sedimentation from several tributaries, reduction in steelhead rearing habitat due to water diversion practices, and migration barriers due to agricultural diversions. Many of the sedimentation problems, however, can be attributed to natural processes. Adverse logging practices in the tributaries to the Trinity River have also been associated with degradation of anadromous fish habitat.

***The Lower Klamath Subbasin (Below Scott River)***

The Lower Klamath Subbasin is defined by the Klamath Task Force starting at Weitchpec to the mouth. Flows and water quality in this section of the main stem Klamath River can be dominated by tributary inflows and releases from Iron Gate Dam during low flow periods. Outside of the high spring run off period, flow patterns are affected by the cumulative water allocation practices in the respective tributaries and operation of the Klamath Project, especially during below normal water years.

Anadromous species which use the main stem Klamath River include spring and fall chinook salmon, spring, fall and winter steelhead, coho, Pacific lamprey and green sturgeon. This section of the main stem represents an important migration corridor for these anadromous species. However, CDFG has presented information that suggests that there is a delay in movement of fish through the lower Klamath (Wallace, CDFG, pers. com.). This information indicates the importance of adequate flows for rearing life stages of fall chinook and other species.  Pre-smolt coho and steelhead originating from upstream and adjacent tributaries must also reside in the lower Klamath main stem until smoltification has completed.  Furthermore, this section of the main stem represents the principal spawning area for green sturgeon.  Although definitive data does not exist to quantitatively assess the status of the anadromous stocks, the available data indicate that fall chinook populations are severely below historical levels.  Populations of coho may reflect levels indicative of the 1960s but are considered below historical numbers.  As has been indicated previously, steelhead are considered to have declined from historical levels.

Estimated habitat use within this section of the Klamath Basin indicates that approximately 100 miles of spawning and incubation habitat are utilized by chinook.  The estimated available coho habitat is approximately 130 miles, while estimated steelhead habitat is approximately 150 miles.  Green sturgeon are considered to utilize approximately 66 miles of the lower main stem Klamath River.  Distribution information for Pacific lamprey is not available but is considered to be approximately the same as that noted for steelhead.  Generally the current distribution of available habitat for these anadromous species are considered to represent historical conditions (see Appendix A).  Although available habitat is near historical levels in terms of miles, alterations in the flow pattern and water quality effectively reduce the amount of effective habitat during seasonal periods.

The primary factors which are considered to potentially limit anadromous fish production in this segment of the main stem Klamath River are associated with historical degradation of habitat due to land-use practices such as timber management as well as by the cumulative effects of upstream flow depletions and alterations in the seasonal hydrograh.  These impacts are associated with degradation of spawning gravel from sedimentation and historically from the creation of migration barriers.  At present, migration barriers in this section of the main stem and tributaries are not considered problematic.  This section of the main stem Klamath River is also known to experience elevated summer water temperatures.  These temperatures can often exceed optimal limits for rearing of juvenile spring chinook, coho, and steelhead.

## Overall Population Trends in Anadromous Species

The following section provides a brief synopsis of the population trends for steelhead, coho, and chinook salmon within the Klamath Basin.  Unless otherwise noted, this material is taken from the coho and steelhead status review documents of the National Marine Fisheries Service and
the Biological Assessment on the Klamath Project 1997 Operations Plan.

### *Steelhead*

Run sizes prior to the 1900s is difficult to ascertain, but were likely to have exceeded up to several million fish.  This is based on the descriptions of the salmon runs near the turn of the century provided in Snyder (1938). The best quantitative historical run sizes in the Klamath and Trinity river systems were estimated at 400,000 fish in 1960 (USFWS 1960, cited in Leidy and Leidy 1984), 250,000 in 1967 (Coots 1967), 241,000 in 1972 (Coots 1972) and 135,000 in 1977 (Boydston 1977). Busby et al. (1994) reported that the hatchery influenced summer/fall-run in the Klamath Basin (including the Trinity River stocks) during the 1980's numbered approximately 10,000 while the winter-run component of the run was estimated to be approximately 20,000. Monitoring of adult steelhead returns to the Iron Gate Hatchery have shown wide variations since monitoring began in 1963. However, estimates during the 1991 through 1995 period have been extremely low and averaged only 166 fish per year compared to an average of 1935 fish per year for 1963 through 1990 period (Hiser 1994). In 1996 only 11 steelhead returned to Iron Gate Hatchery. NMFS considers that based on available information, Klamath Mountain Province steelhead populations are not self-sustaining and if present trends continue there is a significant probability of endangerment (NMFS 1995a). They are a candidate for listing under the ESA at this time.

### *Coho*

At present, coho populations are substantially lower than historical population levels evident at the turn of the century and are listed as threatened under the ESA. NMFS estimated that at least 33 populations are at moderate to high risk of extinction at this time. Coho populations within the Southern Oregon/Northern California Coast Evolutionarily Significant Unit (ESU), which includes the Klamath River Basin, are severely depressed and that within the California portion of the ESU, approximately 36 percent of coho streams no longer have spawning runs (NMFS 1995b). Annual spawning escapement to the Klamath River system in 1983 was estimated to range from 15,400 to 20,000 (USFWS 1983, cited in Leidy and Leidy 1984). These estimates, which include hatchery stocks, could be less than 6 percent of their abundance in the 1940's and populations have experienced at least a 70 percent decline in numbers since the 1960's (CDFG (1994) as cited by Weitkamp et al. 1995). Monitoring of coho returns at the Iron Gate Hatchery have ranged from 0 fish in 1964 to 2,893 fish in 1987 and are highly variable. Based on limited monitoring data from the Shasta River, coho returns have been variable since 1934 and show a great decrease in returns for the past 7 years.

### *Chinook*

The total annual catch and escapement of Klamath River chinook salmon in the period between 1915 and 1928 was estimated at between 300,000 and 400,000 (Rankel 1978). Coots (1973) estimated that 148,500 chinook entered the Klamath River system in 1972. Between 1978 and 1995 the average annual fall chinook escapement, including hatchery-produced fish was 58,820 with a low of 18,133 (CDFG 1995). Overall, fall chinook numbers have declined drastically within the Klamath Basin during this century. As noted previously, spring chinook runs appear to be in remnant numbers within the Klamath River Basin and have been completely extirpated from some of their historically most productive streams, such as the Shasta River (Wales 1951).

## Chapter III - Assessment of Interim Flow Needs

### Introduction

The overall objective of this chapter is to provide estimates of the interim minimum monthly flows necessary to aid in the restoration and maintenance of the aquatic resources within the Lower Klamath River. Instream flow estimates for the major tributaries within the Lower Klamath River Basin will be further addressed in Phase II. The Department has important obligations concerning these resources, including trust responsibility to Klamath Basin Tribes and its statutory responsibilities including the Endangered Species Act and Klamath Basin Restoration Act. These estimates of required flows from the Upper Klamath Basin are primarily for use in the Alternative Dispute Resolution (ADR) process of the Oregon water rights adjudication as well as for the Department's efforts to develop annual and long-term operations plans for the Bureau of Reclamation's Klamath Project. This chapter reviews the basis for establishing the estimated flows available from the Upper Klamath Basin in light of pre-project, historical and current conditions. This is followed by a summary of the monthly species and life stage periodicity of key salmonid species. A review of several techniques considered for the purposes of estimating flow requirements is also provided. Results from the application of the various assessment techniques are provided and compared to various historical and existing recommended flow regimes. The chapter concludes with the specific recommendations for interim minimum monthly flows.

It must be emphasized that the recommended minimum monthly flows in this report are intended as interim recommendations pending completion of more detailed site specific studies and inclusion of tributary instream flows. It is anticipated that refinements will occur as the on-going site specific intensive flow studies are completed (including tributaries) and through the process of adaptive management within the context of other management programs within the Klamath Basin. The basic techniques utilized for estimating the minimum instream flows do not necessarily encompass temperature or water quality needs of the fisheries which have been treated qualitatively in this report. A more rigorous treatment of temperature and water quality is being undertaken as part of Phase II.

### Hydrology

Although a variety of flow analyses have been conducted within the Klamath Basin, two principal works were reviewed extensively for this report: USGS (1995) and Balance Hydrologics, Inc. (1996). In both of these efforts, analyses were conducted to characterize both existing and historical hydrology within the Lower Klamath River Basin on an annual, monthly and daily basis. Although these two reports differ somewhat in their conclusions on the degree or magnitude of changes, differences are attributed to the purposes of the analyses, analytical techniques and underlying assumptions. One of the findings of the USGS is that, on a total annual flow volume basis, flows from the Upper Klamath Basin have not changed 'substantially' over time compared to the total annual flow volume within the Shasta

River (i.e., pre versus post Klamath Project flows in the main stem Klamath River). However, USGS and Balance Hydrologics (1996) both note that annual depletions from the Upper Klamath Basin (i.e., above Iron Gate) are evident and that both monthly and daily flows show the effects of water use in the Upper Klamath Basin. This includes increased flows in the Klamath River from the Lost River diversions during the winter and spring runoff periods which were not quantified as part of this analysis.

What the two analyses found in common is that the estimated average annual outflow from the Upper Klamath Basin at Keno was approximately 1.5 million ac-ft (2,156 cfs). The equivalent 'pre-project' estimated average annual flow at Iron Gate for a normal water year, which accounts for accretions in flow below Keno, was approximately 1.8 million ac-ft (2,575 cfs). This value was derived by adjusting the computed mean annual flow from the 1905 to 1912 period of record at the Keno gage to account for the above normal precipitation pattern during this gaged period (see Balance Hydrologics, Inc., 1996). In comparison, the long term average annual flow at Iron Gate for the 1961 to 1996 period of record is 2060 cfs. The difference between the historical and existing mean annual flow is approximately 515 cfs which corresponds to roughly 372,800 ac-feet. This compares to reported consumptive uses for the Klamath Project (i.e., depletions to the main stem Klamath River below Iron Gate) which have been estimated at between 245,000 and 350,000+ ac-feet depending on water year type, but do not account for consumptive uses above Klamath Lake (BOR, 1992; Larry Dugan, pers. com.). Klamath Project operations may result in as much as 500,000 ac-feet deliveries for agricultural and related demands during dry water years. In addition, water management practices in the Upper Klamath Basin above Iron Gate result in seasonal flows that are now higher in the late winter and early spring and lower during the summer period compared to expected historical flow patterns. There is also a strong indication that flows are more variable now (see Balance Hydrologics, Inc., 1996). This is attributed to the use of water for agricultural purposes, power generation, and perhaps the effect of lost seasonal flow buffering with the loss of storage in Lower Klamath and other Upper Klamath Basin wetlands.

The estimated pre-project flows in the main stem Klamath River at Keno and Iron Gate were selected as the best representative values in the application of the various methods discussed below. The choice of these locations and the estimated pre-project flows is justified since these values integrate basically all the flows leaving Oregon, and represent the best estimate of hydrologic conditions which the anadromous stocks would have evolved under. Several flow statistics were required for the evaluation of instream flows within the context of this report. These are the average annual flow, mean and median monthly flows, and various monthly flow duration statistics. These statistics represent values necessary for the application of several of the hydrology based instream flow methods used in the analyses in this report as discussed below.

### *Iron Gate Mean Annual, Average and Median Monthly Flows*

The mean annual, and average monthly flows below Keno and Iron Gate for a normal water year were taken from Balance Hydrologics, Inc. (1996) and provided in Table 1. As noted above, the Iron Gate values were obtained from the 1905-1912 gage readings at Keno adjusted to a normal water year flows and include estimated normal year accretions between the Keno and Iron Gate gages. The BOR concurred that, at present, these mean annual and monthly flows were the best estimates of pre-project flows in the main stem Klamath River below Iron Gate Dam (Larry Dugan, pers. com.).

The median monthly flows at Iron Gate were derived from the Keno daily discharge data for the 1905-1912 period of record by computing the monthly flow duration statistics (see Appendix B). These values were then adjusted by 1.04 following the work of Balance Hydrologics, Inc (1996) to approximate an average water year. The monthly average water year accretions listed in Table 1 were then added to obtain the estimated median monthly flows for Iron Gate shown in Table 2.

Table 1. Estimated pre-project mean annual and average monthly flows in cfs at Keno and Iron Gate Dam. (Note: MAF = Mean Annual Flow)

| | Keno 1905-1912 Mean (cfs) | Keno Adjusted Index (1.04) Normal Year | Percent of MAF | Monthly Normal Year Accretions (cfs) | Iron Gate Normal Mean (cfs) | Percent of MAF |
|---|---|---|---|---|---|---|
| Oct | 1236 | 1188 | 0.57 | 348 | 1536 | 0.60 |
| Nov | 1518 | 1460 | 0.70 | 349 | 1809 | 0.70 |
| Dec | 1915 | 1841 | 0.89 | 517 | 2358 | 0.92 |
| Jan | 2295 | 2207 | 1.06 | 620 | 2827 | 1.10 |
| Feb | 2670 | 2567 | 1.24 | 764 | 3331 | 1.29 |
| Mar | 3027 | 2911 | 1.40 | 693 | 3604 | 1.40 |
| Apr | 3326 | 3198 | 1.54 | 659 | 3857 | 1.50 |
| May | 3182 | 3060 | 1.48 | 567 | 3627 | 1.41 |
| Jun | 2630 | 2529 | 1.22 | 401 | 2930 | 1.14 |
| Jul | 1809 | 1739 | 0.84 | 408 | 2147 | 0.83 |
| Aug | 1202 | 1156 | 0.56 | 347 | 1503 | 0.58 |
| Sep | 1060 | 1019 | 0.49 | 351 | 1370 | 0.53 |
| Mean (cfs) | 2156 | 2073 | | | 2575 | |

Table 2. Estimated pre-project median monthly flows in cfs at Keno and Iron Gate Dam.

| | Keno 1905-1912 Median (cfs) | Keno Adjusted Index (1.04) Normal Year | Monthly Normal Year Accretions (cfs) | Iron Gate Normal Year Median (cfs) |
|---|---|---|---|---|
| Oct | 1240 | 1192 | 348 | 1540 |
| Nov | 1495 | 1438 | 349 | 1787 |
| Dec | 1830 | 1760 | 517 | 2277 |
| Jan | 2250 | 2163 | 620 | 2783 |
| Feb | 2640 | 2538 | 764 | 3302 |
| Mar | 2690 | 2587 | 693 | 3280 |
| Apr | 3100 | 2981 | 659 | 3640 |
| May | 3060 | 2942 | 567 | 3509 |
| Jun | 2480 | 2385 | 401 | 2786 |
| Jul | 1760 | 1692 | 408 | 2100 |
| Aug | 1160 | 1115 | 347 | 1462 |
| Sep | 1050 | 1010 | 351 | 1361 |
| Mean (cfs) | 2063 | 1984 | | 2486 |

### ***Historical (Pre-Project) Water Year Classifications below Iron Gate***

Monthly flows indicative of five water year classifications were also estimated. These flows were used for comparative purposes of what different types of water year flow patterns may have looked like under pre-project conditions compared to the recommended minimum instream flow requirements. These water year classifications were based on the same exceedance ranges of mean annual flow as utilized in the 'Trinity River Flow Evaluation Study'. Specifically, the mean annual flow for each water year at the Iron Gate gage for the period of record 1961 to 1996 was used to compute the corresponding mean annual flow duration curve (see Figure 1).

Water year classifications were associated with the following exceedance ranges: extremely wet (< 12 percent); wet ($\geq$ 12 percent and < 40 percent); normal ($\geq$ 40 percent and < 60 percent); dry ($\geq$ 60 percent and < 88 percent); and critically dry ($\geq$ 88 percent). The average of all mean annual flows which fell into a particular water year classification category was then assigned as the mean annual flow for that water year category as listed in Table 3. The mean annual flow for each water year category was then partitioned into monthly values utilizing the percent of mean annual flow based on the pre-project monthly flow distributions at Iron Gate Dam (see Table 1) and are provided in Table 4.

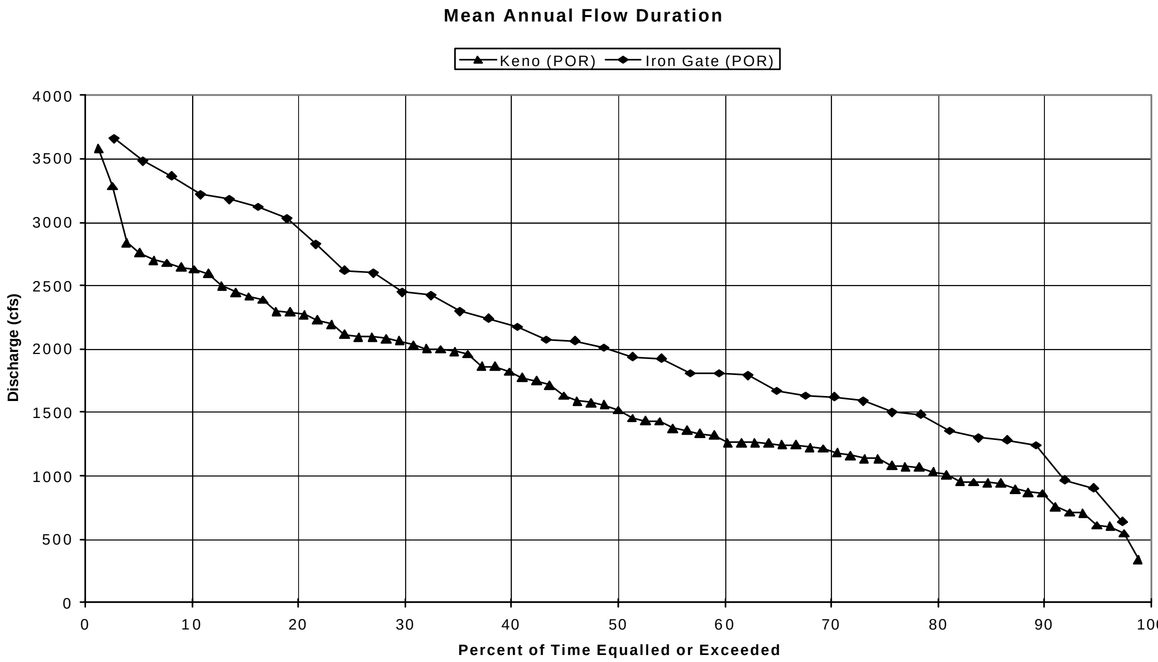


**Figure 1**. Mean annual flow duration for Keno (1905-1912) and below Iron Gate Dam (1961-1996) period of record.

It is recognized that use of the Iron Gate period of record reflects varying amounts of flow depletions by water year type and that these annual flow volumes are underestimated by upper basin depletions but this approach is considered to be a workable approximation for comparative purposes. It is also recognized that the monthly flow distributions can change depending on water year type, but a more rigorous approach utilizing correlations of historical gage data from the upper Klamath Basin and estimated historical flow depletions was beyond the scope of this project. Also, existing daily flow records at Iron Gate are significantly impacted by water allocation practices and therefore their use was discarded as a basis to derive these pre-project water year flow patterns on a monthly basis.

Table 3. Iron Gate mean annual flow exceedance values derived from the 1961-1996 period of record and corresponding water year classifications.

| Extremely Wet | | | Wet | | | Normal | | | Dry | | | Critically Dry | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Exceedance | Year | Flow (cfs) | Exceedance | Year | Flow (cfs) | Exceedance | Year | Flow (cfs) | Exceedance | Year | Flow (cfs) | Exceedance | Year | Flow (cfs) |
| 2.70 | 196 | 3660 | 16.22 | 197 | 3120 | 40.54 | 196 | 2172 | 62.16 | 198 | 1794 | 89.19 | 198 | 1240 |
| 5.41 | 198 | 3482 | 18.92 | 198 | 3026 | 43.24 | 196 | 2074 | 64.86 | 199 | 1670 | 91.89 | 199 | 967 |
| 8.11 | 198 | 3362 | 21.62 | 199 | 2824 | 45.95 | 197 | 2064 | 67.57 | 196 | 1631 | 94.59 | 199 | 901 |
| 10.81 | 197 | 3217 | 24.32 | 197 | 2621 | 48.65 | 198 | 2011 | 70.27 | 196 | 1621 | 97.30 | 199 | 640 |
| 13.51 | 197 | 3178 | 27.03 | 198 | 2598 | 51.35 | 196 | 1938 | 72.97 | 198 | 1588 | | | |
| | | | 29.73 | 198 | 2449 | 54.05 | 199 | 1927 | 75.68 | 196 | 1502 | | Aver | 937 |
| | Aver | 3380 | 32.43 | 197 | 2421 | 56.76 | 196 | 1807 | 78.38 | 197 | 1485 | | | |
| | | | 35.14 | 197 | 2294 | 59.46 | 197 | 1807 | 81.08 | 199 | 1355 | | | |
| | | | 37.84 | 196 | 2241 | | | | 83.78 | 198 | 1300 | | | |
| | | | | | | | Aver | 1975 | 86.49 | 197 | 1281 | | | |
| | | | | Aver | 2622 | | | | | | | | | |
| | | | | | | | | | | Aver | 1523 | | | |

Table 4. Estimated natural mean monthly flow patterns (cfs) by water year category at Iron Gate Dam based on mean annual flows using the 1961-1996 period of record.

| | Ext. Wet | Wet | Normal | Dry | Critically Dry |
|---|---|---|---|---|---|
| MAF (cfs) | 3380 | 2622 | 1975 | 1523 | 937 |
| Oct | 1938 | 1503 | 1132 | 873 | 537 |
| Nov | 2380 | 1846 | 1391 | 1072 | 660 |
| Dec | 3002 | 2329 | 1754 | 1353 | 832 |
| Jan | 3598 | 2791 | 2102 | 1621 | 997 |
| Feb | 4186 | 3247 | 2446 | 1886 | 1160 |
| Mar | 4746 | 3681 | 2773 | 2138 | 1316 |
| Apr | 5214 | 4045 | 3047 | 2350 | 1446 |
| May | 4989 | 3870 | 2915 | 2248 | 1383 |
| Jun | 4123 | 3199 | 2409 | 1858 | 1143 |
| Jul | 2836 | 2200 | 1657 | 1278 | 786 |
| Aug | 1884 | 1462 | 1101 | 849 | 522 |
| Sep | 1662 | 1289 | 971 | 749 | 461 |

### *Iron Gate Monthly Flow Exceedance Value Estimates*

Pre-project median monthly flows (i.e., 50 percent exceedance) as well as 40, 60, 70, 80 and 90 percent exceedance values were estimated at Iron Gate for use in several of the instream flow analyses. The daily flow records at Iron Gate Dam are sufficiently impacted by water allocation practices that their direct use for computing monthly exceedance values was deemed inappropriate. The required flows for specific monthly exceedance values were derived by computing the monthly flow-exceedance values using the daily flow records for the 1905-1912 period of record at Keno (see Appendix B). Since this period of record corresponds to an above normal precipitation patten, the flows were adjusted at each of these exceedance values by 1.04 to derive a 'normal year' estimate for each of the flow-exceedance values at Keno. The corresponding flow for each exceedance value at Iron

Gate was then obtained by adding normal year accretions below Keno for the 40, 50, and 60 percent exceedance values. Although Balance Hydrologics, Inc. (1996) infer that accretions for wet, normal, dry and critically dry water years were previously computed by CH2MHill for the BOR (see Page 15 in Balance Hydrologics, Inc., 1996), only normal and wet year accretions were reported. The BOR provided estimated accretions for dry years (1977, 1981, 1987, 1992, 1994), which were averaged for each month and then added to the flows associated with the 70, 80, and 90 percent exceedance values to obtain these estimates at Iron Gate. These values are provided in Table 5. It is recognized that this particular approach to estimating the required flow values associated with particular exceedance ranges for use in the hydrology based instream flow approaches discussed below likely over estimates to some degree the flows at high exceedance ranges and to some degree under estimates the flows at low exceedance ranges. However, since most of the hydrology based methods are oriented toward estimation of minimum flows rather than optimal flows, this bias is not considered problematic for the intent of this work. Given the objectives of this report and in light of the depleted conditions of the fish resources in the Klamath River Basin, a conservative approach which provides protection of the aquatic resources is deemed most appropriate. Although a more detailed examination of flows based on mass balance simulations using MODSIM or other models will be undertaken as part of Phase II, the simulation of flows below Iron Gate which include accretions and depletions suffers from the same lack of quantitative data requiring similar but different types of assumptions.

Table 5. Estimated Iron Gate pre-project flows (cfs) for associated monthly exceedance values used in various hydrology methods and where derived from an analysis of the daily flow records at Keno for the 1905-1912 period of record.

| Exceedance | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 | 2889 | 3351 | 3674 | 3784 | 3692 | 2988 | 2379 | 1626 | 1524 | 1540 | 1801 | 2344 |
| 50 | 2783 | 3302 | 3280 | 3640 | 3509 | 2786 | 2100 | 1462 | 1361 | 1540 | 1787 | 2277 |
| 60 | 2591 | 3033 | 3231 | 3572 | 3192 | 2670 | 1879 | 1366 | 1332 | 1463 | 1743 | 2209 |
| 70 | 2269 | 2567 | 2659 | 2935 | 2791 | 2389 | 1691 | 1273 | 1196 | 1320 | 1640 | 1877 |
| 80 | 2125 | 2423 | 2620 | 2935 | 2714 | 2245 | 1585 | 1182 | 1162 | 1272 | 1582 | 1839 |
| 90 | 2096 | 2375 | 2466 | 2771 | 2560 | 2034 | 1460 | 1128 | 1068 | 1186 | 1476 | 1820 |

## Life History Requirements

A considerable amount of information has been developed on the life history requirements and seasonal utilization of the Klamath River for anadromous species within the Klamath Basin (i.e., coho, chinook, and steelhead). However, very little data presently exists for other important tribal trust species, such as sturgeon and lamprey. Because of the lack of specific information for these species, only the anadromous species were specifically considered. However, if the habitat requirements of the anadromous species and their respective life stages are met, then it is assumed (given lack of data to suggest otherwise) that adequate protection for other tribal trust species within the river corridor will be met. This is often an assumption that must be made when conducting more intensive site-specific studies (e.g., IFIM) where a lack of sufficient information exists to develop habitat suitability criteria for all target species of interest.

Excellent summaries on life history requirements for the anadromous species within the Klamath Basin can be found in Birk (1996), Shaw et al. (1997), and Leidy and Leidy (1984). The basic life history needs in terms of consideration of timing can be summarized with a species and life stage monthly periodicity table. Table 6 was adapted from Birk (1996) and Shaw et al. (1997) and revised by the DOI Technical Review Team to be broadly representative of the life stage periodicity for anadromous species within the main stem Klamath River and for use in this report for the various analyses. This table is provided as a generalized overview of the timing and use of the main stem Klamath River in order to focus the assessment of flow regimes throughout the year. The monthly periodicity is represented by range defined by the earliest and latest month reported by the various investigators and technical review team.

### The Ecological Basis of Flow Regimes for Aquatic Resources

River ecosystems create a temporally and spatially variable physical, chemical, and biological template within which fish and other aquatic resources can exist if they possess the proper suite of physiological, behavioral, and life history traits (Poff and Ward, 1990; Orth, 1987). This environmental template and species specific set of traits is often characterized as a multi-dimensional niche of environmental conditions (e.g., envelopes of depth, velocity, substrate, temperature) and resources (e.g., food, space) which describes the environmental conditions necessary for species survival. Suitable environmental conditions and resources must be available in terms of their quantity, quality and timing in order to sustain a viable long term population (Statzner, 1988; May and MacArthur, 1972; Pianka, 1974; Colwell and Futuyma, 1971). Because a variety of factors and resources are required to meet the life history requirements of species, the short and long term success of individuals and ultimately populations can be limited by a single factor or by a combination of factors. In river systems, the suitability of environmental conditions for aquatic resources are directly related to the characteristics of the flow regime. Therefore, quantification of flow requirements which will provide for the long term protection of the aquatic resources must be undertaken from an ecological basis in light of the flow dependent environmental factors which may limit these aquatic resources.

As an important initial step in meeting these requirements, the determination of interim minimum instream flow needs within the main stem Klamath River below Iron Gate Dam which will protect and aid in the restoration of the anadromous species is required. This need is evident given the concern raised by fisheries biologists on appropriate flows at the time of the construction of Iron Gate Dam, the fact that the existing FERC flow schedule was a negotiated settlement in which flows were not always associated with biologically based recommendations, the depleted status of the stocks which has resulted in listed and proposed listing of species under the ESA, tribal, commercial, and recreational harvest have been curtailed or eliminated, and the historical and current concern of the resident state, federal, and tribal fisheries biologists and program managers over the adequacy of the existing flow regime below Iron Gate Dam (and other tributaries) (see Appendix C).

In essence, an ecologically based flow regime must incorporate the spatial and temporal flow conditions necessary to ensure long-term protection of the aquatic resources. The flow regime must maintain the linkage between the physical, chemical, and biological components of river ecosystems, which result in the formation and persistence of fish and macroinvertebrate habitat. Quantification methodologies currently recognize that suitable flow regimes can be broken down into four basic flow components (Petts et al., 1995; Hill et al., 1991). These four flow components are fish habitat base flows, channel maintenance flows, riparian flows, and valley maintenance flows. Although the specific methods by which each of these flow components are quantified vary, all components are essential to maintain the ecological health of the stream system (Hill et al., 1991).

Table 6. Life stage monthly periodicity for anadromous species in the Klamath River.

| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chinook Salmon Holding and Migration** | | | | | | | | | | | | |
| Adult Fall Run | | | | | | | | | | | | |
| Adult Late Fall Run | | | | | | | | | | | | |
| Spring Run | | | | | | | | | | | | |
| **Chinook Salmon Spawning** | | | | | | | | | | | | |
| Fall Run | | | | | | | | | | | | |
| Late Fall Run | | | | | | | | | | | | |
| Spring Run | | | | | | | | | | | | |
| **Chinook Salmon Emergence** | | | | | | | | | | | | |
| Fall Run | | | | | | | | | | | | |
| Spring Run | | | | | | | | | | | | |
| **Chinook Salmon Rearing** | | | | | | | | | | | | |
| Fall Run | | | | | | | | | | | | |
| Late Fall Run | | | | | | | | | | | | |
| Spring Run | | | | | | | | | | | | |
| **Chinook Salmon Outmigration** | | | | | | | | | | | | |
| Fall Run | | | | | PEAK | PEAK | PEAK | PEAK | PEAK | PEAK | PEAK | |
| Spring Run | PEAK | | | | | PEAK | PEAK | PEAK | | | | PEAK |
| Yearlings | | | | | | | | | | | | |
| **Coho Salmon** | | | | | | | | | | | | |
| Holding and Migration | | | | | | | | | | | | |
| Coho Spawning | | | | | | | | | | | | |
| Coho Emergence | | | | | | | | | | | | |
| Coho Rearing | | | | | | | | | | | | |
| Coho Outmigration | | | | | PEAK | PEAK | PEAK | PEAK | PEAK | PEAK | | |
| **Steelhead** | | | | | | | | | | | | |
| Holding and Migration | | | | | | | | | | | | |
| Summer/Spring Run | | | | | | | | | | | | |
| Fall Run | | | | | | | | | | | | |
| Winter Run | | | | | | | | | | | | |
| Downstream Run | | | | | | | | | | | | |
| Half-pounder Run | | | | | | | | | | | | |
| Steelhead Spawning | | | | | | | | | | | | |
| Steelhead Emergence | | | | | | | | | | | | |
| Steelhead Rearing and Outmigration | | | | | | | | | | | | |

This report focuses on the fish habitat base flow component. Quantification of the remaining flow components were approximated given the existing state of the physical system, which presently allows propagation of these higher flow events within the main stem Klamath River. Specifically, with the exception of sustained drought periods, uncontrolled releases from the Upper Klamath Basin below Iron Gate Dam continue with sufficient frequency and magnitude, which are likely to protect the physical processes within the main stem Klamath River necessary for channel and riparian maintenance flows. This flow component has not been quantified as part of Phase I, but will be addressed under work for Phase II.

Efforts directed at the evaluation of minimum instream flow requirements that aid in the restoration and maintenance of aquatic resources has already resulted in the development and application of a large number of methodologies over the past several decades and continues at an elevated rate today. Excellent reviews of many of the techniques developed and applied within the United States and elsewhere can be found in Reiser et al. (1989), CDM (1986), EPRI (1986), and Gore (1989). A broad area of research within the "discipline" of instream flow assessments is focused on modification or extension of existing methodologies, while other efforts are being directed at development and application of new tools. This is driven to some extent by the current ecosystem management objectives of resource agencies and a growing consensus among both researchers and practitioners that the disciplinary basis upon which the fundamental science and analytical procedures are developed, validated and applied in instream flow assessments will continue to benefit from a broader ecological perspective (Orth, 1995; Stanford, 1994).

This has lead to research focused on the development and application of tools and assessment frameworks aimed at a quantitative characterization of the factors controlling fisheries resources rather than continued application of tools for evaluation of a single target species from the limited perspective of physical habitat. This broadly includes research on trophic level dynamics, process oriented delineation of flow induced changes in the physical and biological components of the aquatic environment (e.g., the Trinity River Flow Evaluation Report), and in the development of broader based ecological frameworks for the evaluation of impact assessments or restoration efforts in aquatic ecosystems (e.g. Johnson and Law, 1995; Johnson et al., 1995; Hearne et al., 1994; Capra et al., 1995; Leclerc et al., 1995; Addley, 1993; Nehring and Anderson, 1993; Muhar et al., 1995).

Other pertinent research within the broader arena of instream flows has focused on the delineation of key life history characteristics in terms of ontogenetic shifts in habitat use under natural and induced flow variability (Heland et al., 1995; Bardonnet and Gaudin, 1990; Bardonnet et al., 1993; Crisp and Hurley, 1991), the relationship between flow and macroinvertebrate community dynamics (Lancaster and Hildrew, 1993; Gore, 1989; Jowett et al., 1991; Weisberg et al., 1990; Statzner et al., 1991), and the importance of trophic level dependancies between macroinvertebrates and fish (Filber and Hawkins, 1995; Bevelhimer, 1996; Weisberg and Burton, 1993; Easton and Orth, 1992; Roell and Orth, 1994). Efforts employing mechanistic individual based bioenergetics, physical habitat based approaches utilizing population models, and multi-variate statistical approaches have also produced encouraging results (Addley, 1993; Jager et al., 1993; Bovee et al., 1994; Hill and Grossman, 1993; Jowett, 1992). This has included results based on linking community level distribution and abundance with spatially explicit delineations of the habitat mosaic at the meso-scale (Aadland, 1993; Dibble and Killgore, 1994; Bain, 1995; Jowett, 1992). A broader view of the river corridor as an integrated ecosystem has also provided excellent research on methods and frameworks for delineating the process driven linkages between flow, sediment transport, channel structure, and the riparian community (Hill et al., 1991; Nillson et al., 1991; Rabeni and Jacobson, 1993; Stromberg et al., 1991; Stromberg, 1993).

Many of these techniques will be applicable to the Klamath Basin for quantification of instream flow needs and in the application of an adaptive management program as part of on-going management efforts. However, most are beyond the specific scope of this report but have been incorporated into on-going efforts under Phase II.

**Applied Assessment Methods**

A total of 14 analysis methods covering a range of analytical techniques were initially considered for use in the evaluation of minimum flow needs in the lower Klamath River Basin for the aquatic resources (Table7). A concise description of these various methods can be found in CDM (1986). Although a wide array of potential assessment methods were considered, the lack of requisite data precluded many of these methods for consideration at this time.

Table 7. Instream Analysis Methods Reviewed.

**<u>Hydrology Based Methods</u>**

Hoppe Method
New England Flow Recommendation Policy
Northern Great Plains Resource Program Method
Washington Base Flow Method
Tennant Method

**<u>Field Based Methods</u>**

| | |
|---|---|
| Idaho Method | Indicator Species Method |
| Instream Flow Incremental Methodology | Oregon Usable Width Method |
| U.S. Forest Service Region 6 Method | Washington Spawning Method |
| Washington Rearing Method | Waters Method |
| Weighted Usable Width Method | |

The potential applicability of each method was evaluated based on underlying assumptions, type of system(s) in which the method was developed or applied, target species, previous applications to large rivers with anadromous species and specific data requirements. The USFWS/USGS have collected data at a number of study reaches which characterize important habitats for anadromous fish species in the main stem Klamath River below Iron Gate Dam. These data include channel topography, water surface elevations and velocity profiles. After a review of these data, the field based methods highlighted in Table 7 and discussions with the DOI Technical Review Team, the use of these data for the various field based methods was deferred to Phase II. This is primarily a function of field collection of additional velocity data sets and desire to undertake a comprehensive review of available Habitat Suitability Criteria (HSC) for the target anadromous species and life stages rather then reliance on use of the HSC developed for the Trinity River.

The hydrology methods discussed below were applied in deriving flow estimates within the main stem Klamath River. Each method is described briefly and the manner in which the method was applied or adopted is discussed. Methods were modified or adapted based the physical or biological setting of the Klamath River and input from the review team. It must be stressed that the approach taken in this report (and the philosophy of the review team) was that if a method was broadly applicable from a biological perspective and where basic assumptions could be reasonably met, it was applied. This approach attempts to avoid a prior or post priori justification of a single method and strives to treat each method as providing independently derived estimates based on valid but unique underlying assumptions. The estimates from each technique were then 'aggregated' based on a simple average to derive the final flow recommendations on a monthly basis.

## <u>Hydrology Based Methods</u>

### *Hoppe Method*

This method was developed from studies on the Frying Pan River, Colorado and estimates flow requirements from percentiles on an annual flow duration curve for salmonid species. A flow that is equaled or exceeded 17 percent of the time is set for a 48 hour period to maintain flushing flows. As noted previously, this component of the flow regime is not addressed quantitatively in this report. The flow that is equaled or exceeded 40 percent of the time is recommended for protection of spawning flows and the flow that is equaled or exceeded 80 percent of the time is recommended to maintain flows for food production and aquatic cover. In essence, this approach strives to protect the higher flow component associated with the spring high flow spawning period and to provide survival habitat in terms of food production and physical habitat during the low flow periods.

The biological rationale for this approach was adapted for the Klamath River by using the monthly 40 percent exceedance flows to protect spawning and incubation for the September through February period, the monthly 60 percent exceedance flows during March through

May period to protect incubating eggs and the monthly 80 percent exceedance flows for the June through August period for food production and protection of rearing habitats for fish. The actual monthly exceedance values were utilized in order to preserve the characteristics of the pre-project flow patterns within a normal water year. The exceedance values for each monthly time period were derived from Table 5 and the resulting instream flows for each month utilizing this approach are provided in Table 8.

Table8. Estimated monthly instream flows based on application of the Hoppe Method.

| | Exceedance | Estimated MIF |
|---|---|---|
| Oct | 40 | 1540 |
| Nov | 40 | 1801 |
| Dec | 40 | 2344 |
| Jan | 40 | 2889 |
| Feb | 40 | 3351 |
| Mar | 60 | 3231 |
| Apr | 60 | 3572 |
| May | 60 | 3192 |
| Jun | 80 | 2245 |
| Jul | 80 | 1585 |
| Aug | 80 | 1182 |
| Sep | 40 | 1524 |

***New England Flow Recommendation Policy***

This method is based on the assumption that aquatic resources have evolved to survive the most severe or adverse environmental conditions in the most stressful month of the year and encompasses both salmonid and invertebrate species. Utilizing hydrology records, the aquatic base flow is set as the median August flow, unless superceded by spawning requirements which are equivalent to the historical (pre-project) median flow throughout the spawning period. Where inadequate flow records exist or where flows have been altered from water projects, recommendations are derived from the average median August flows computed from representative streams in the region in terms of cubic feet per square mile (cfsm). In this instance, the ‘default’ flows are 0.5 cfsm for all times of the year unless superceded by spawning and incubation flows which are defined as 1.0 cfsm in the fall/winter or 4.0 cfsm in the spring for the entire applicable spawning and incubation periods.

This method was adopted for application in the Klamath by computing the flow associated with the 50 percent exceedance value for the spawning period from September to February using the daily flow records at Keno for the 1905-1912 period of record. The computed flow (1630 cfs) was then adjusted by 1.04 and the monthly accretions for each of these months were added to the flow estimate. A similar approach was taken for the incubation/emergence period during February through May using Keno daily flow records for the 1905-1912 period of record. The computed 50 percent exceedance flow of 2870 cfs then adjusted by 1.04 and the normal year accretions for each month were added to this value. Finally, the daily gage data for August at Keno using the daily flow records from the 1905-1912 period of record was computed and then adjusted by 1.04. The monthly normal water year accretions were then added to each month. The highest monthly required flow was then selected for each month and set as the instream flow requirement. The corresponding monthly values are provided in Table 9.

Table 9. Estimated monthly instream flows based on application of the New England Aquatic Base Flow Method.

| | August | Spawning | Inc/Emergence | Maximum MIF | Accretions | Estimated MIF |
|---|---|---|---|---|---|---|
| Oct | 1462 | 1567 | | 1567 | 348 | 1915 |
| Nov | 1462 | 1567 | | 1567 | 349 | 1916 |
| Dec | 1462 | 1567 | | 1567 | 517 | 2084 |
| Jan | 1462 | 1567 | | 1567 | 620 | 2187 |
| Feb | 1462 | 1567 | 2760 | 2760 | 764 | 3524 |
| Mar | 1462 | | 2760 | 2760 | 693 | 3453 |
| Apr | 1462 | | 2760 | 2760 | 659 | 3419 |
| May | 1462 | | 2760 | 2760 | 567 | 3327 |
| Jun | 1462 | | | 1462 | 401 | 1863 |
| Jul | 1462 | | | 1462 | 408 | 1870 |
| Aug | 1462 | | | 1462 | 347 | 1809 |
| Sep | 1462 | 1567 | | 1567 | 351 | 1918 |

### ***Northern Great Plains Resource Program Method***

This method was developed from the assumption that established aquatic resource populations (independent of species composition) are a result of normal or average flows as opposed to 'abnormal' flows (e.g., extreme low or high flow components of the flow regime). The approach is based on the computation of mean monthly flows from the existing period of record and in the situation where the mean monthly flows are normally distributed, the 't' statistic is used the establish the bounds for normal flows. That is, extreme values are discarded. Where mean monthly flows are not normally distributed, then professional judgement is utilized to censor the data records.

The daily flow records for each retained month are then used to construct monthly flow duration curves and the flow that is equaled or exceeded 90 percent of the time is specified as the required flow to protect the aquatic ecosystem in that month. Further adjustments are made to recommended flows during the spring runoff period using a flow that is 'near the mean annual flow of record' during the high flow months. During low flow months, additional reductions in the flow may be made where 'sharing' of water with beneficial out-of-stream uses may be warranted. These two flow adjustments are based on professional judgement and negotiations. Adjustments for low flow months was deemed inappropriate given the status of the anadromous stocks in the Klamath River Basin and as noted previously, the high flow component is not considered under Phase I.

Since the existing historical flow records at Keno have such a short period of record, all the data were utilized to derive monthly flow durations. The corresponding 90 percent exceedance values were then obtained from the monthly flow duration analyses. In this instance, the estimated dry year accretions were added to each monthly value after adjusting by 1.04 to eliminate the above normal year bias. The corresponding recommended monthly flows are provided in Table 10.

Table 10. Estimated monthly instream flows based on application of the Northern Great Plains Resource Program Methodology.

| | Estimated MIF |
|---|---|
| Oct | 1186 |
| Nov | 1476 |
| Dec | 1820 |
| Jan | 2096 |
| Feb | 2375 |
| Mar | 2466 |
| Apr | 2771 |
| May | 2560 |
| Jun | 2034 |
| Jul | 1460 |
| Aug | 1128 |
| Sep | 1068 |

### ***Tennant Method***

This basic methodology attempts to protect the health of aquatic habitat based on an observed correlation between habitat conditions and flow regime as a percentage of the mean annual flow. The technique was developed from a variety of streams which were dominated by salmonid species but has been broadly applied to a wide range of systems including non-salmonid systems. Table 11 lists the criteria developed by Tennant for different levels of aquatic habitat protection.

Tennant is broadly accepted in the literature as a reconnaissance-level technique. It was previously employed by Trihey (1996) to estimate instream flow requirements for tribal trust species in the Klamath River. These estimated flows subsequently served as a basis by which the 'Modified Yurok' flow regime proposal was developed for consideration in Klamath Project operations. The modified Yurok proposal was developed through a facilitated workshop of Klamath Basin fisheries biologists and represents a DELPHI based recommendation.

Table 11. Instream Flow Regimes for Fish, Wildlife, Recreation and Related Environmental Resources

| | **Recommended Base Flow Regimes (% Mean Annual Flow)** | |
|---|---|---|
| Flow Type | Oct - Mar | Apr - Sep |
| Flushing Flow | 200 | 200 |
| Optimum Range | 60-100 | 60-100 |
| Outstanding Range | 40 | 60 |
| Excellent | 30 | 50 |
| Good | 20 | 40 |
| Fair | 10 | 30 |
| Poor or Minimum | 10 | 10 |
| Severe Degradation | 0-10 | 0-10 |

At its most fundamental level, the Tennant Method relies on the available long term gage data to derive an exceedance based flow level. As such, it inherently incorporates the range of water year variability by nature of the flow-exceedance basis of the computations. What remains difficult however, is the selection of an 'appropriate' percent of the mean annual flow to utilize and how then this flow volume should be partitioned between various months based on the life history needs of the target species and life stages. There is no widely accepted 'method' or 'rule-of-thumb' that can be relied on to select the flow category for use in defining a flow recommendation (see Table 11). Comparative studies between Tennant and more site-specific studies would suggest that flow criteria between the 30 percent and 60 percent ranges of MAF are common (Wesche 1973, Wood and Whelan 1962, Joy et al. 1981, Orth and Maughan 1981, Prewitt and Carlson 1979, Nelson 1980). It recognized that many of these applications targeted species and river systems that are very different from the Klamath, but remain roughly consistent across species and systems. Nelson (1980) suggests that the Tennant Method may in some instances overestimate instream flow requirements compared to site-specific analyses in larger river basins. However, this is not known to be generally true across a variety of systems. Fundamentally, the use of Tennant for estimating minimum instream flows remains widely applied and accepted.

Given the objectives of this analysis and a desire to maintain a conservative view toward protection of the aquatic resources within the Klamath River, an 80 percent basis of MAF was selected for use in this application of Tennant. This represents the mid-point of the Optimal Range for protection (see Table 11) . This percent of the mean annual flow was partitioned between all months within the year based on the percent distribution of pre-project mean monthly flows (see Table 1). In this instance, the application of the Tennant Method was 'modified' to allow the hydrograph to mimic natural flows patterns as is commonly undertaken with this technique for adjustment of seasonal flow patterns (e.g., Ott and Tarbox 1977, Bayha 1978, Estes 1985, Fernet 1987, Trihey 1996). The resulting instream flow values are provided in Table 12.

Table 12. Estimated monthly instream flows based on application of the Tennant using the mid-point of the Optimum Range or 0.8 of the MAF.

| | Estimated MIF (cfs) |
|---|---|
| Oct | 1229 |
| Nov | 1447 |
| Dec | 1886 |
| Jan | 2262 |
| Feb | 2665 |
| Mar | 2883 |
| Apr | 3086 |
| May | 2902 |
| Jun | 2344 |
| Jul | 1718 |
| Aug | 1202 |
| Sep | 1096 |

### *Washington Base Flow Method*

This methodology estimates the required instream flow levels based on a ranking of the stream in terms of wildlife, fisheries, scenic and esthetic, water quality, navigational, and other environmental values. The technique is applicable to salmonid systems. The average rating is then used in a nomographic solution to obtain a flow-duration percentile. This flow-duration percentile is then used to estimate the flow recommendation using the flow duration curve for the river. In the absence of site specific rankings in each of these categories, the highest stream ranking (i.e., 24) was chosen and the solution for Western Washington during the low flow period was selected for use with this technique. This choice is justified given the high value fisheries, ESA considerations, high recreational values of the main stem Klamath River below Iron Gate Dam including both sport fishing and recreational boating, and the importance of this river for overall environmental concerns to tribal trust resources.

The resulting flow-duration statistic would be the 60 percent exceedance. This basic technique was modified for this report to utilize the 60 percent exceedance value on a monthly basis in order to preserve the natural pattern of seasonal flows. The monthly 60 percent flow exceedance values based on the daily discharges at Keno for the 1905-1912 period of record were used and the normal year monthly accretions were added to each month (see Appendix B). The preservation of the seasonal pattern of natural flows is considered important in light of the flow dependant cues of anadromous species to flow timing in the main stem in conjunction with tributary flows. The resulting instream flow estimates from this technique are provided in Table 13.

Table 13. Estimated monthly instream flows based on application of the Washington Base Flow Method.

| | 60 Percent Exceedance | Accretions (cfs) | Estimated MIF (cfs) |
|---|---|---|---|
| Oct | 1160 | 348 | 1508 |
| Nov | 1450 | 349 | 1799 |
| Dec | 1760 | 517 | 2277 |
| Jan | 2050 | 620 | 2670 |
| Feb | 2360 | 764 | 3124 |
| Mar | 2640 | 693 | 3333 |
| Apr | 3030 | 659 | 3689 |
| May | 2730 | 567 | 3297 |
| Jun | 2360 | 401 | 2761 |
| Jul | 1530 | 408 | 1938 |
| Aug | 1060 | 347 | 1407 |
| Sep | 1020 | 351 | 1371 |

## Review of Field Based Methods

The application of the field based methods will be delayed for consideration under Phase II pending completion of additional field work, identification of appropriate HSC for each of the anadromous species and life stages and development of analytical approaches wherein substrate and cover use can be included. The preliminary analyses conducted utilizing the hydraulic data from the USFWS/USGS and HSC from the Trinity River clearly showed for example, that failure to include appropriate cover functions in the analysis for the early life stages produced results that did not match known habitat use within the Klamath River based on extensive field observations by resident biologists. Although some of the preliminary results for specific species and life stages could have been utilized in this report, the use of partial results for specific methods was considered inappropriate and potentially misleading. These technical issues are presently being addressed under Phase II in collaboration with the technical review team.

## Recommended Flows

### *Iron Gate Dam to the Shasta River*

Since each of the various techniques were considered to provide a independent estimate of required flows based on differing but valid biological assumption, the individual monthly values for each method were averaged across all techniques to derive the 'best estimate' of the recommended minimum monthly instream flows. The resulting monthly instream flow recommendations for Iron Gate to the Shasta River are provided in Table 14.

Table 14. Summary of pre-project normal water year mean and median flows at Iron Gate Dam, instream flow estimates (cfs) by method and recommended monthly Minimum Instream Flows (MIF) below Iron Gate Dam.

| | Iron Gate Mean Flows | Iron Gate Median Flows | Hoppe | NEABF | NGP | Tennant | Washington | MIF |
|---|---|---|---|---|---|---|---|---|
| Oct | 1536 | 1540 | 1540 | 1915 | 1186 | 1229 | 1508 | 1476 |
| Nov | 1809 | 1787 | 1801 | 1916 | 1476 | 1447 | 1799 | 1688 |
| Dec | 2358 | 2277 | 2344 | 2084 | 1820 | 1886 | 2277 | 2082 |
| Jan | 2827 | 2783 | 2889 | 2187 | 2096 | 2262 | 2670 | 2421 |
| Feb | 3331 | 3302 | 3351 | 3524 | 2375 | 2665 | 3124 | 3008 |
| Mar | 3604 | 3280 | 3231 | 3453 | 2466 | 2883 | 3333 | 3073 |
| Apr | 3857 | 3640 | 3572 | 3419 | 2771 | 3086 | 3689 | 3307 |
| May | 3627 | 3509 | 3192 | 3327 | 2560 | 2902 | 3297 | 3056 |
| Jun | 2930 | 2786 | 2245 | 1863 | 2034 | 2344 | 2761 | 2249 |
| Jul | 2147 | 2100 | 1585 | 1870 | 1460 | 1718 | 1938 | 1714 |
| Aug | 1503 | 1462 | 1182 | 1809 | 1128 | 1202 | 1407 | 1346 |
| Sep | 1370 | 1361 | 1524 | 1918 | 1068 | 1096 | 1371 | 1395 |

These values are compared to pre-project, historical (Klamath Project Operations) and previous monthly instream flows in Table 15. The MIF recommendations can be compared to the water year type classifications in Table 4 which reflect between 250,000 and 500,000 acre-feet depletions from the Upper Klamath Basin depending on water year type.

Table 15. Comparison of pre-project mean flows in a normal year, recommended monthly instream flows and previous instream flow recommendations and historical Iron Gate releases (1961-1996) period of record (all flows are in cfs).

| | Pre-project Mean | MIF | Iron Gate 1961-96 | FERC | Trihey | Yurok |
|---|---|---|---|---|---|---|
| Oct | 1536 | 1476 | 1664 | 1300 | 1200 | 1300 |
| Nov | 1809 | 1688 | 2142 | 1300 | 1500 | 1500 |
| Dec | 2358 | 2082 | 2744 | 1300 | 1500 | 1500 |
| Jan | 2827 | 2421 | 2825 | 1300 | 1500 | 1500 |
| Feb | 3331 | 3008 | 3047 | 1300 | 1500 | 1500 |
| Mar | 3604 | 3073 | 3601 | 1300 | 1500 | 1500 |
| Apr | 3857 | 3307 | 2970 | 1300 | 2000 | 2000 |
| May | 3627 | 3056 | 2046 | 1000 | 2500 | 2500 |
| Jun | 2930 | 2249 | 1050 | 710 | 1700 | 1700 |
| Jul | 2147 | 1714 | 758 | 710 | 1000 | 1300 |
| Aug | 1503 | 1346 | 970 | 1000 | 1000 | 1300 |
| Sep | 1370 | 1395 | 1303 | 1300 | 1000 | 1300 |

What is apparent for the summary comparisons of the Iron Gate to Shasta River results, is that basically the flow recommendations during the September through March period would have been met under historical operations of the Klamath Project, while actual flows were below the recommend flows during the remaining months of the year. The current lack of sufficient storage (e.g., increased retention from restored wetlands and marshes, or increased capacity of existing facilities) in the Upper Klamath Basin precludes the ability to hold water during the early spring period when higher than pre-project flows are now typical. This lack of adequate storage may prevent the release of water necessary for the attainment of the recommended flows due to high demands during the later spring and summer period to meet existing water allocations within the Upper Klamath Basin (i.e., above Iron Gate).

The results indicate that in general, the current recommended minimum instream flows below Iron Gate Dam are higher than previous recommendations. The major difference in the recommended flow regime and that of the modified Yurok and Trihey proposed flow regimes is the attempt to track the shape of the natural pattern in the hydrograph. This is considered important in terms of linking the magnitude and timing of the flow releases below Iron Gate to better match the pre-project relationship of higher flows within tributaries. This pattern of flow is anticipated to provide a better ecological flow regime which maintains not only the physical but ecological linkages between the main stem and tributary systems. The recommended flows are substantially higher than the existing FERC flows. A comparison of the FERC flow regime and the water year based classification in Table 4, shows that the FERC flow regime is basically at or below critically dry exceedance flows. Note that the water year volumes reported in Table 4 are underestimated by the magnitude of the annual depletions (i.e., 250,000 - 500,000 acre-feet) depending on water year type. This is particularly evident during the summer and early fall period when low flows can contribute to high water temperatures below Iron Gate Dam. The FERC recommended flow regime also departs substantially from the natural flow regime of the Klamath River throughout the whole year. Concerns raised during the construction of Iron Gate Dam by resident fisheries scientists were raised over the appropriate minimum flows and clearly the record shows that the final FERC flow regime was a negotiated settlement and not derived from strong biological evaluations of the flow needs of the fishery in the main stem Klamath River below Iron Gate Dam (see Appendix C).

### ***Evaluation of Water Temperatures***

At this juncture, the various techniques employed implicitly assume that other factors such as water quality or temperature are not limiting. This of course is not true for the main stem Klamath River below Iron Gate Dam where deleterious water temperatures and low dissolved oxygen have been associated with fish kills during the late summer low flow period. Bartholow (1995) reviewed the available data on temperature effects on anadromous species in the Klamath River found that the main stem Klamath experiences elevated temperatures deleterious to salmonids from May through October. Bartholow considered acute thermal effects for salmonids, especially egg and larval life stages were to be expected to occur at mean daily water temperatures of 20 C or for consecutive exposures at a weekly mean temperature at 15 C. He concluded that water temperatures in the Klamath are presently marginal at best for anadromous salmonids for much of the summer and early fall period. The USGS presently utilizes the EPA Quality Criteria for Water within SIAM which considers acute thermal conditions for coho and chinook salmon as 22 C and chronic exposures to occur at 16 C. Empirical observations of fish mortalities below Iron Gate during the summer period dictates that the flow dependant nature of the thermal regime on a seasonal basis needs to be factored into the flow recommendations.

As a preliminary screening of the relationship between flow and temperature below Iron Gate, Mr. Mike Deas (U.C. Davis) provided simulations of daily water temperatures for mid-August from Iron Gate Dam (RM 190.1) to the USGS Gage near Seiad Valley (RM 128.9). Simulations were completed for steady state releases from Iron Gate for at least 7 days prior to August 14 to ensure no transients in the system. Because tributary flow contributions changes daily and water temperature changes hourly, a dynamic component exists in the August 14 mean/max/min data, but it is minor. Simulated flows were made between 200 and 3000 cfs. At low flow rates, water temperature results are compromised due to physical representation of river geometry where modeled flows are excessively shallow due to fixed trapezoidal cross sections. Maximum daily temperatures are probably too high and minimums too low for flows <500 cfs. Mean temperatures are probably representative. The effect of tributary contributions on maximum and minimum temperatures may not be representative. Lower river results are probably more realistic due to increased tributary and accretion contributions. Based on these caveats, only the simulated data from 500 to 1500 cfs were used in the following assessments. Although these simulations are only a first approximation, the results shown in Figures 2 and 3 for mean and maximum daily temperatures respectively, demonstrate a clear relationship between flow release volume and thermal response in the main stem Klamath River at least downstream to the Scott River, where ambient conditions then dominate.

It is evident that a clear relationship exists between increasing flow rates and reduction in the both the mean and maximum daily temperatures in the longitudinal profile of temperatures below Iron Gate Dam. This is attributed to the known relationship between higher flow volumes and damping of the range in maximum daily temperatures due to higher thermal mass with increasing flow rates. Previous work by PacifiCorp (1995) and Bartholow (1995) indicate that Iron Gate Dam may not have sufficient storage (or a deep water release point) sufficient to mitigate thermal effects with cool/cold water releases downstream of Iron Gate Dam for any substantial length of time and may place required cool water needs of the Iron Gate Dam Hatchery at risk. However, flow reductions in dry or critically dry years during late summer and early fall clearly have the potential to exacerbate thermal effects down stream of Iron Gate Dam.

Additional temperature modeling was conducted by the USGS for the recommended monthly instream flows in the Draft Final Report below Iron Gate Dam based on 1996 observed meteorological conditions. Only summary results were obtained from the BOR in the form of daily temperature plots below Iron Gate and Seiad which indicate that a 0.0 C to 0.6 C range in increased mean daily temperatures. Although the overall average difference compared to the 1996 baseline averaged less than 0.4 C for the July through September period, this magnitude is likely within the noise of model input parameters given the gross estimations of wind speed, relatively humidity, air temperature, shading, and other model parameters. The temperature differential at Seiad was less than the ranges found immediately below Iron Gate Dam.

The results from these temperature simulations clearly reinforce the concerns of the effects of low flow released during the summer period below Iron Gate Dam. The data also suggest that the recommended flow regimes will provide an incremental improvement to the thermal regime below Iron Gate Dam in terms of both the mean and maximum daily temperatures. It should be noted that prior to the construction of Iron Gate Dam as well as under natural conditions, a substantial volume of the flows in the vicinity of Iron Gate Dam were dominated by cold water inflows from springs and tributaries and would have contributed to the maintenance of cool water refugia within this reach of river. Historical fisheries data clearly show that prior to building Iron Gate Dam that this section of the Klamath River (i.e., above present Iron Gate Dam) supported anadromous species which targeted these cold water inflows (Robert Franklin and Kent Bulfinch, pers. com.). Although existing conditions within the Klamath River in terms of Iron Gate Dam, upstream reservoirs, and Klamath Lake result in higher than would be expected temperature releases from Iron Gate Dam compared to natural conditions, this is not justification to consider lower flow releases as adequate to meet the anadromous species needs at this time. The temperature results basically support the higher flow recommendations within the main stem Klamath River below Iron Gate Dam compared to existing flow regimes.

These results, in conjunction with the flow recommendation analysis would suggest that instream flow recommendations should not be adjusted for water year types represented by dry and critically dry water years pending more refined analyses based on site specific methodologies. It is also recognized that alterations and refinements in the derived flow estimates will be made in the future based on availability of additional data (e.g., USFWS/USGS cross section data) and application of additional assessment techniques being undertaken as part of Phase II.

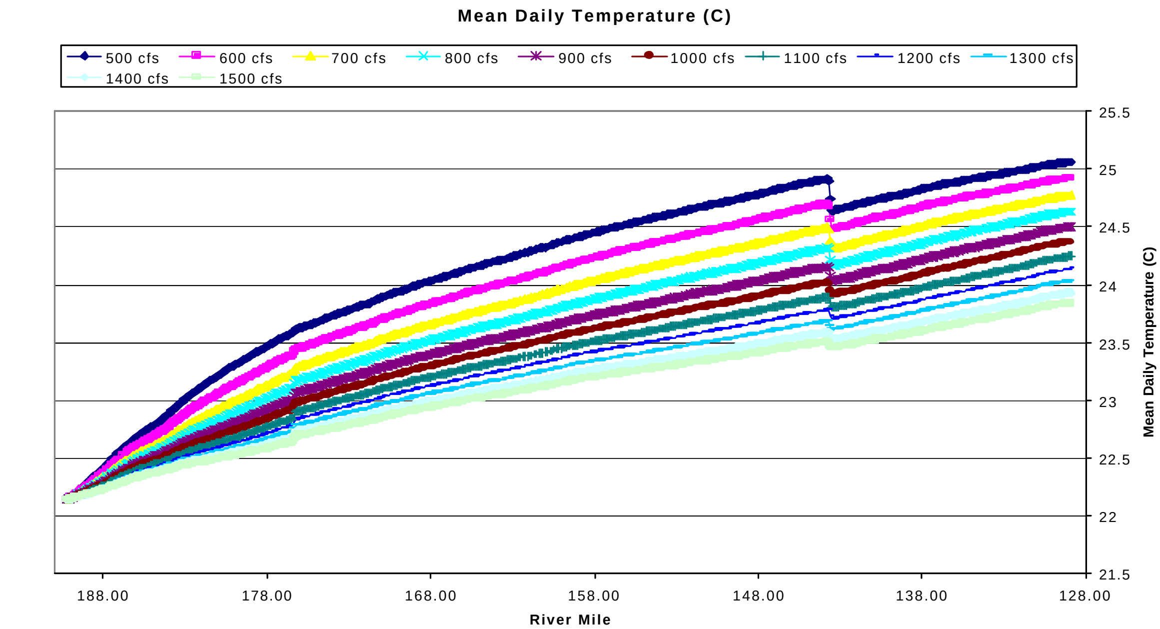


**Figure 2**. Longitudinal profiles of simulated mean water temperatures below Iron Gate Dam typical of mid-August meteorological conditions.

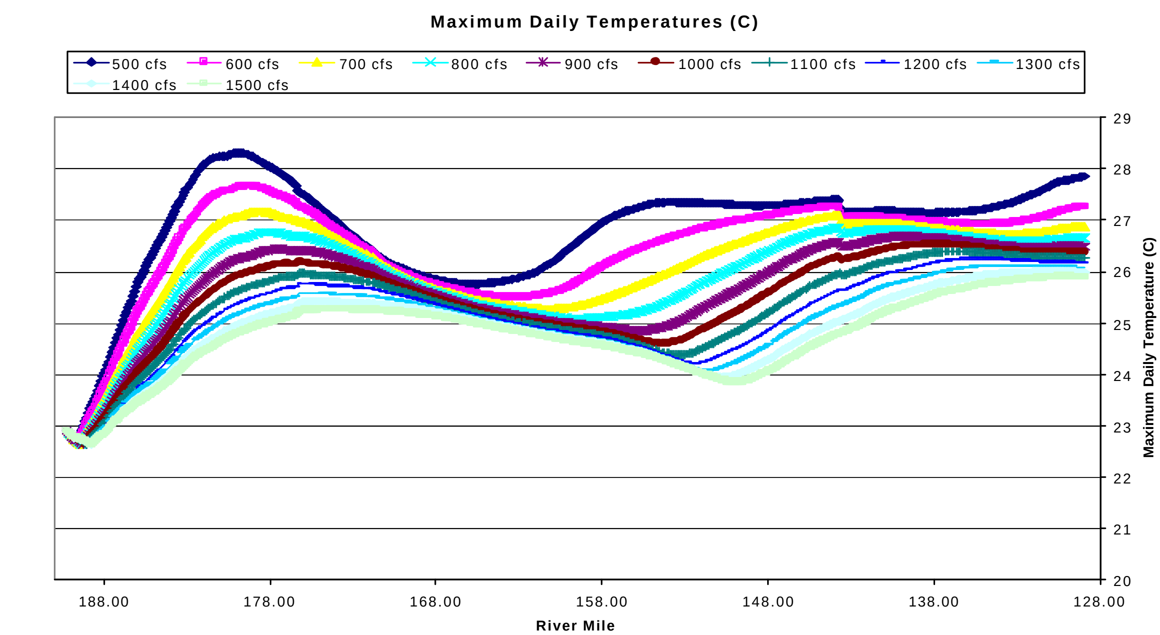


**Figure 3**. Longitudinal profiles of simulated mean water temperatures below Iron Gate Dam typical of mid-August meteorological conditions.

### ***Shasta River to Scott River***

The 1933 to 1996 gage data for the Shasta River near Yreka was used to compute the long term mean annual flow (173 cfs) and subsequently to estimate the mean monthly flows as shown in Table 16 and are underestimated due to diversions and depletions associated with agricultural practices within the basin.

Table 16. Estimated mean monthly flows (cfs) in the Shasta River near Yreka (1933-1996) period of record.

| | |
|---|---|
| October | 151.3 |
| November | 194.6 |
| December | 276.6 |
| January | 324.2 |
| February | 337.2 |
| March | 309.1 |
| April | 201.5 |
| May | 131.5 |
| June | 96.9 |
| July | 43.2 |
| August | 38.1 |
| September | 74.6 |

Furthermore, it is desirable to maintain the linkage between both flow timing and magnitudes for the main stem Klamath River and tributaries in order to maximize the opportunity for emigration and immigration of anadromous salmonids. Therefore, the average instream flow recommendations derived for the Iron Gate to Shasta River were adjusted by adding the average monthly ‘accretions’ corresponding to the mean monthly flows in Table 16 to estimate the instream flows for the Shasta to Scott River reach. Pending more specific work within the tributaries as well as the main stem of the Klamath River, this approach was considered conservative in terms of maintaining flow linkages both within the two reaches of the main stem of the Klamath River as well as between the main stem and the Shasta River. The resulting instream flows are presented in Table 17.

### ***Monthly Transition Flows***

Existing ramping rates for this facility are presently being evaluated by PacifiCorp and Reclamation during the fall of 1999 as directed in the 1999 Biological Opinion, and will be addressed in a more quantitative manner as part of the Phase II effort. However, because of the possibility of stranding of young-of-the-year salmonids in April, May and June, it would be prudent to limit ramping rates to no more than 50 cfs per hour (Larry Dugan, pers. com.)

Table 17. Recommended monthly instream flows for the Shasta to Scott River reach.

| | Iron Gate MIF | Shasta Flows | Mean | Monthly Estimated MIF |
|---|---|---|---|---|
| Oct | 1476 | | 151 | 1627 |
| Nov | 1688 | | 195 | 1883 |
| Dec | 2082 | | 277 | 2359 |
| Jan | 2421 | | 324 | 2745 |
| Feb | 3008 | | 337 | 3345 |
| Mar | 3073 | | 309 | 3382 |
| Apr | 3307 | | 201 | 3508 |
| May | 3056 | | 131 | 3187 |
| Jun | 2249 | | 97 | 2346 |
| Jul | 1714 | | 43 | 1757 |
| Aug | 1346 | | 38 | 1384 |
| Sep | 1395 | | 75 | 1470 |

## **Fisheries Habitat Maintenance Flow Component**

As previously noted, the techniques discussed above are generally more relevant for recommendations for the fisheries base flow component but are not necessarily suitable for estimating the physical processes important to channel or riparian maintenance flow needs. These two elements of the flow regime can conceptually be regarded as a fisheries habitat maintenance flow since it attempt to maintain the dynamic linkage between flow, sediment transport, and the riparian community within the river channel. These combined processes ultimately determine the quantity and quality of available fisheries habitat. The quantitative estimation of this component of the flow was beyond the scope of this work and will be addressed in Phase II. However, previous work by other investigators discussed above has shown that flows with a return period of 1 to 3 years may be adequate for maintaining the physical and biological linkage between flow, sediment transport and riparian dynamics in channels. The Tennant Method suggests a value equal to 200 percent of the mean annual flow (see Table 11) which would correspond to approximately 5150 cfs although some data suggests that flows associated with 300 percent of the mean annual flow may be more appropriate (CDFG, pers. com.). A review of discharge data at Iron Gate shows that flows of these magnitudes are being met frequently under existing operations and therefore should not pose a problem in meeting this component of the flow regime. Pending more site specific analyses, the Tennant Method flow regime is recommended for the protection of this component of the flow regime. Based on the historical distribution of flows within the main stem Klamath below Iron Gate (see Table 1) these flows should be applied during the January to June period when above normal water year conditions exits within the upper Klamath Basin.

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